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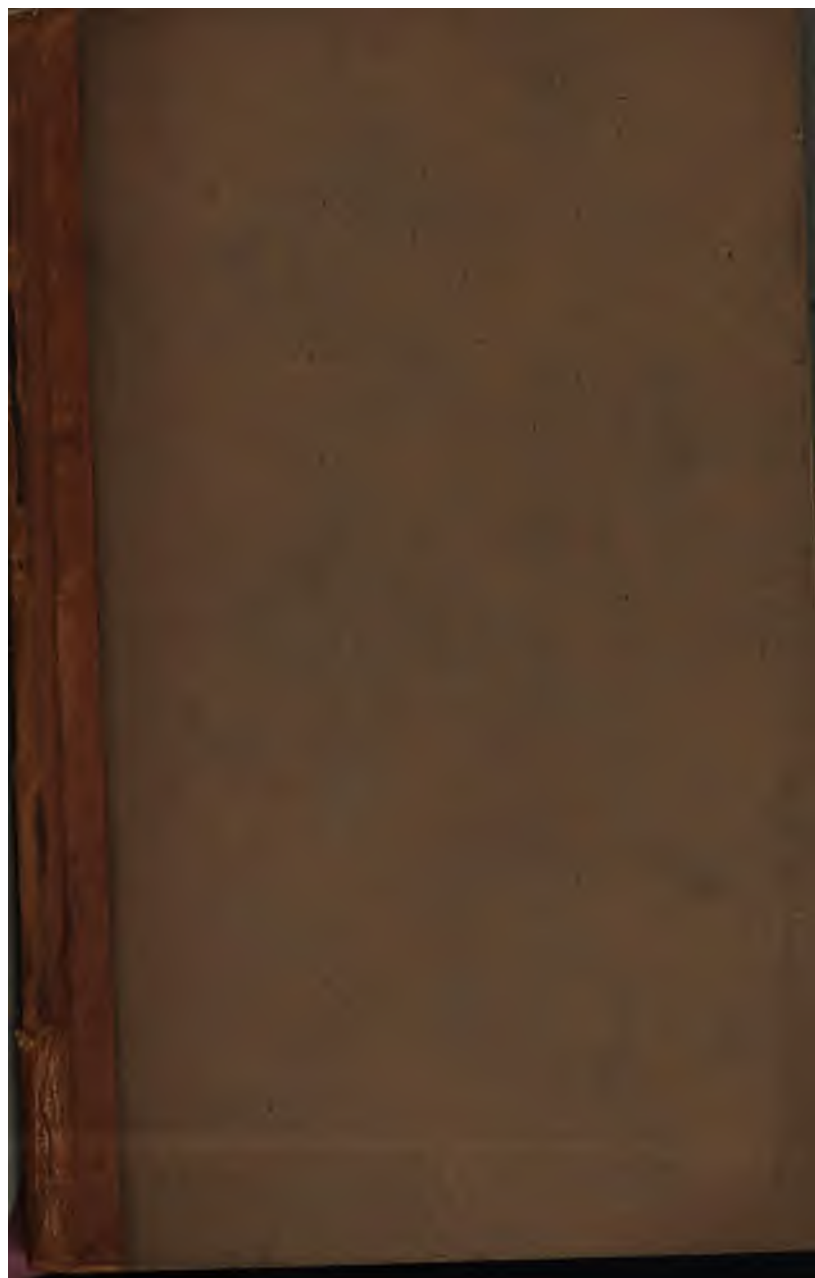
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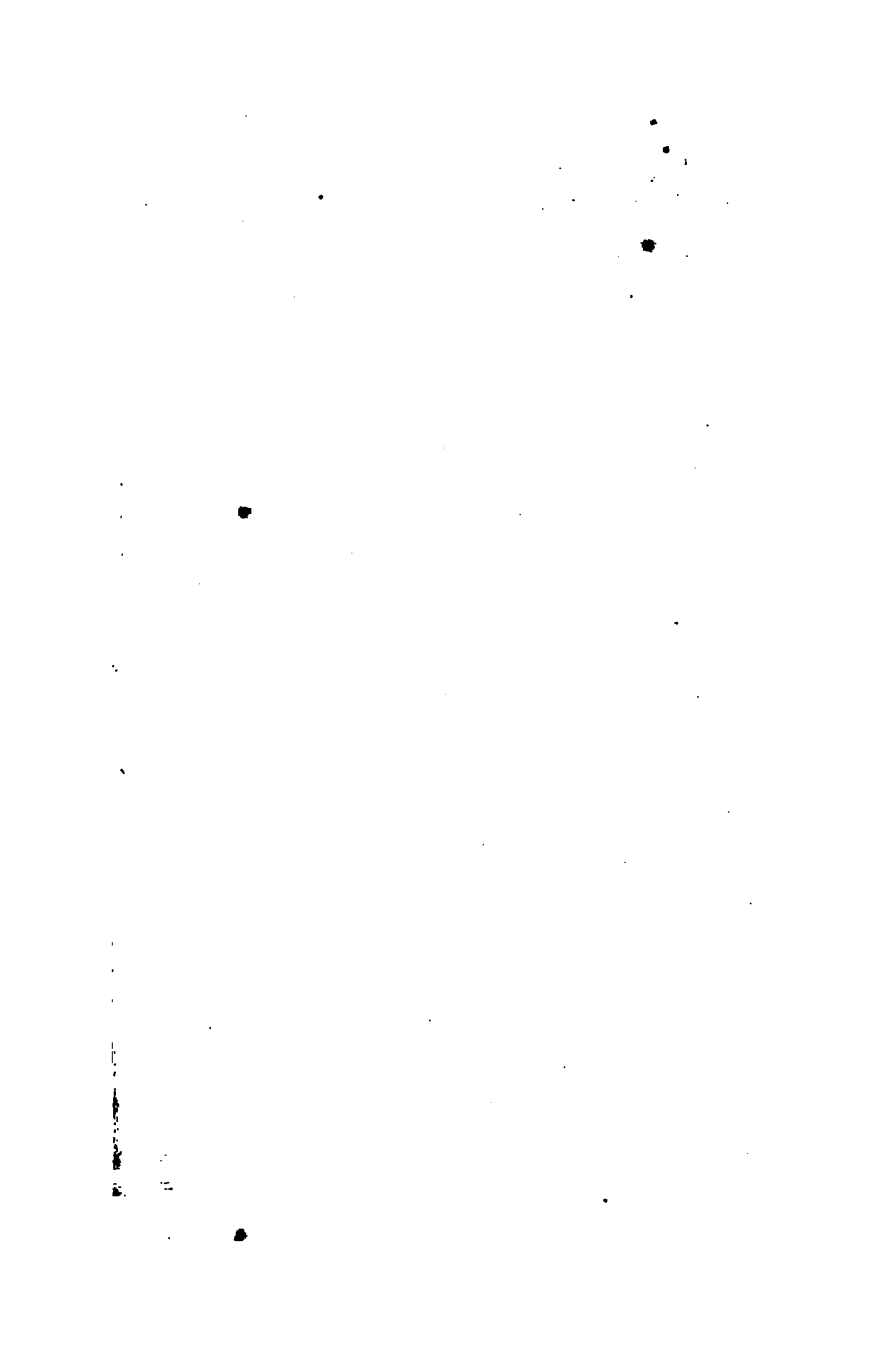
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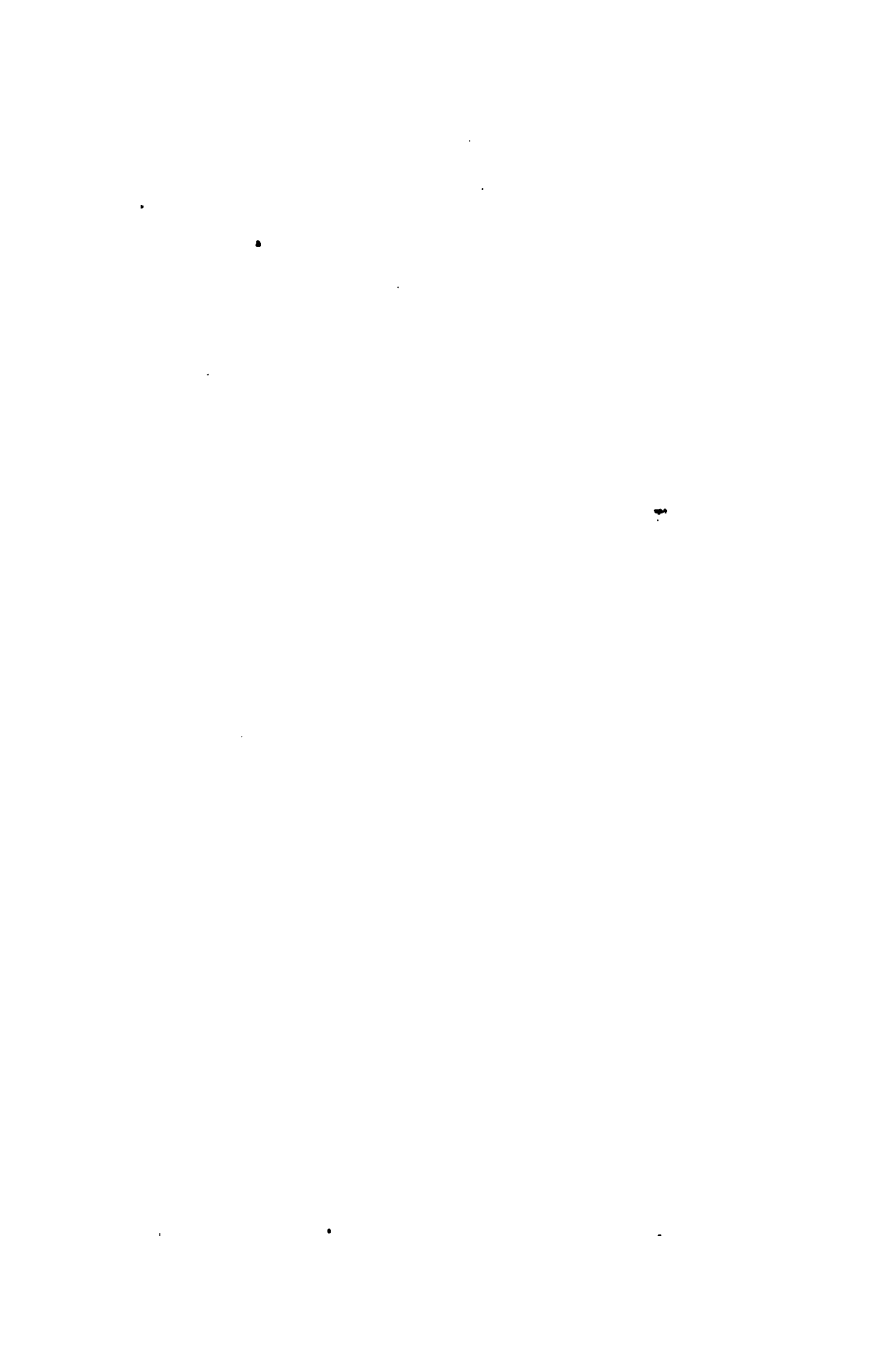
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A CATECHISM
OF THE
PHYSIOLOGY AND PHILOSOPHY
OF
BODY, SENSE, AND MIND.



A CATECHISM
OF THE
PHYSIOLOGY AND PHILOSOPHY
OF
BODY, SENSE, AND MIND.

For use in Schools and Colleges, and in Private Study.

BY

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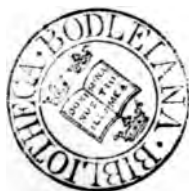


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TO
RICHARD FOWLER, M.D., F.R.S.,
SULTING PHYSICIAN TO THE SALISBURY AND WILTS
COUNTY INFIRMARY, ETC.,

WHO,
MORE THAN SIXTY YEARS AGO, HAD DISTINGUISHED HIMSELF BY HIS
VALUABLE CONTRIBUTIONS TO PHYSIOLOGY—

WHO,
THE CULTIVATION OF THE PHILOSOPHY OF THE MIND, HAS APPROVED
HIMSELF A WORTHY DISCIPLE OF DUGALD STEWART—

WHO,
FTER A LONG AND HONOURABLE CAREER AS A PRACTICAL PHYSICIAN,
EMPLOYS THE LEISURE OF A DIGNIFIED RETIREMENT IN
PHILOSOPHICAL PURSUITS—

AND WHO,
ABOVE ALL, IS ESTEEMED AND VENERATED FOR HIS CHRISTIAN AND
SOCIAL VIRTUES, BY A LARGE CIRCLE OF FRIENDS—

The following Pages,

INTENDED AS AN INTRODUCTION TO THE STUDY OF
E PHYSIOLOGY AND PHILOSOPHY OF BODY, SENSE AND MIND,

Are Dedicated,

TH FEELINGS OF THE SINCEREST ATTACHMENT AND RESPECT,
BY HIS FRIEND,

THE AUTHOR.

P R E F A C E .

No one can have remained quite a stranger to the phenomena of living beings in general; and, still less, indifferent to the workings of his own body and mind. To every one, therefore, questions in physiology and philosophy must have suggested themselves—How comes it that our body grows and is nourished from the food we eat and the air we breathe? What is the mechanism by which our limbs are moved, or by which we speak?—On the other hand, how is it we feel, taste, smell, hear, see? How is it we know and think? How is it we will to move or not to move?

The answers to these and similar questions, so far as answers can be given, constitute the basis

on which is founded the knowledge of ourselves and of the relations in which we stand to the world around us.

Though then very imperfectly known, the physiology and philosophy of body, sense and mind were comprised in the disquisitions on Nature held by the sages of ancient Greece with their disciples. In its special developments, however, the physiology of the body was subsequently, in a great measure, studied apart from the philosophy of mind, and became more and more subservient to medicine. Indeed, it was the importance of its application to that art which especially incited to the persevering cultivation of which the study of the functions of the body has long been the object. As prevention, however, is better than cure, the application of physiology to the preservation of health is of still more importance, even, than that to the cure of disease. And, fortunately, it is an application which we have it, in general, more completely in our power to make; for, knowing physiological

laws, we may often, if we will, act in conformity to them, and thus escape the operation of many of the exciting causes of disease.

Important, however, as this bearing on hygienics is, it would be taking too low ground to present it as the reason for recommending the introduction of physiology as a subject of general study in our Schools and Colleges. Besides, the truth is, that physiology must be studied in as special and technical a manner for sanitive as for medical practice. Elementary physiology can only be expected to teach the reasonableness of the hygienic precepts dictated by the experience of the physician.

It is mainly as a branch of liberal knowledge, then, let it be understood, that the rudiments of the physiology of the body, in conjunction with the philosophy of the mind, claim to be included in the curriculum of general education. Teaching us the distinction between the physical and psychical in our being, and showing what are the foundations and limits of natural knowledge, the

study in question prepares us to observe correctly, and to appreciate at their just value, facts concerning ourselves and the relations in which we stand to the world around us. In short, rightly studied, there is no subject in the higher departments of education, whether viewed as a discipline of the mind, or in respect of the knowledge actually inculcated, which contributes more to open up the understanding than the Physiology and Philosophy of Body, Sense, and Mind.

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INTRODUCTION.

SECTION I.—ORGANIZATION AND LIFE IN GENERAL.

WHAT is meant by *organization*, as applied to plants and animals?

The peculiar composition and construction of body, proper to these beings.

Mention an example in which organization is exhibited in its simplest phase.

A nucleated cell—which is the element, in respect to form, out of which, more or less metamorphosed and variously combined, plants and animals are constructed.

Describe the structure of a nucleated cell.

It is a microscopical vesicle composed of heterogeneous or dissimilar parts, solid and fluid, viz.—cell wall, nucleus, and contents which, as organs or instruments, serve different purposes in the economy of the cell.

What is the *life* of the vegetable or animal body?

Under the name of *life* is personified the peculiar mode of activity of organized structure.

Indicate the simplest and most general manifestation of that peculiar mode of activity, whether in plants or animals.

Nutrition.

Describe nutrition as it goes on in a nucleated cell.

A nucleated cell imbibes matters in solution from around it, which it assimilates and incorporates with its own body. At the same time this process of absorption and composition goes on, an opposite one of decomposition and excretion is in operation. The effect is, that the organized and living cell is preserved and maintained as such.

What are the characteristics of minerals, as compared with plants and animals?

Minerals are altogether destitute of organization, and cannot, of course, manifest the activity peculiar to that construction of body. In short, they are *inorganic* and *lifeless*. Hence, in minerals, no molecular movement of decomposition and recomposition—such as we have said constitutes nutrition—goes on; but, in the absence of decomposing forces, chemical or physical, from without, they remain unchanged.

Involved in the attributes of organization and life, what other characteristics, deserving of notice, are there of plants and animals?

There are characteristics in respect to duration, mode of termination, and mode of origin, of their existence.

What is there to be said of organized and living beings, in respect to the duration of their existence?

Organized and living beings enjoy only a limited duration of existence, though they differ very much from each other in that respect.

What is there to be said of the mode of termination of the existence of organized and living beings?

Organized and living beings are, in their nature, subject to decay. After subsisting for a prescribed period, in the course of which they pass through certain phases of being—growth, maturity, and decline—the nutritive movements of decomposition and recomposition at last cease. The body is now said to be *dead*. It has become subject to the ordinary laws of inorganic matter, which it had previously the power of resisting and controlling, to a certain extent. The result is, that its organized structure is broken up and destroyed.

Death being thus the lot of organized and living beings, how are the vegetable and animal creations preserved from eventual extinction?

By the faculty of reproduction—a faculty which may be viewed as constituting, in the economy of living beings, a necessary adjunct to nutrition, to which it is, in its essence, closely allied.

Give an example of reproduction in its simplest form.

The formation of new cells at the expense of pre-existing ones, either by endogenous or exogenous development. In its simplest form, reproduction may thus be considered as depending on the capability which part of an organized and

living being possesses, under certain conditions, when separated from the rest, to continue independently the nutritive movements—to grow and to be developed into a new being.

Sum up what you have been saying of the death and reproduction of plants and animals.

Though plants and animals enjoy only a temporary existence as individuals, their existence as races is of indefinite duration; their temporary existence, as individuals, being maintained by nutrition—their indefinitely prolonged existence, as races, secured by reproduction. In short, though the individual dies, the race continues to live.

You are here speaking in reference to the present geological epoch, are you not?

Yes; for the extinction of races and the creation of new have been shown by geologists to have repeatedly taken place in former phases of the earth's development.

Extinction of races and creation of new! But is there not reason to believe, with some naturalists, that the plants and animals of later geological epochs are not, properly speaking, new creations, but merely the descendants, with successively higher development, of those of preceding epochs?

Though the higher animals exhibit in their organization higher developments of the same plan as that according to which the lower are constructed, there is no indication of any such thing as descent with progressive development, whereby animals of a lower grade of one epoch have had for their descendants animals of a higher grade of organization in the succeeding epoch—a progressive development which,

through a long series of epochs, has at last produced a monkey from a worm, a man from a monkey !

State what seems to be the reality in regard to the succession of races on the earth.

So far as our knowledge extends, races of animals continue, generation after generation, essentially unchanged throughout the long period of their existence as races ; and when, in former conditions of the earth, new races of higher development have arisen to replace old races of lower development which had become extinct, this has been by a new exertion of creative power at the fiat of the Almighty, and not by the spontaneous transmutation of a pre-existing race, still less by anything like a spontaneous generation.

Is the idea of a spontaneous generation of plants or animals not well founded ?

The idea can now only be looked on as a wild hypothesis : every fact with which the science of organic beings has of late years been enriched having only more and more decidedly shown that the appearance of plants and animals, where none existed before, is no proof that the organisms have been spontaneously produced. There are, in fact, everywhere scattered abroad, germs from pre-existing organisms so minute as to elude ordinary observation, but ready to spring into life when and wherever the necessary conditions offer.

Do minerals present anything noteworthy in respect to their duration, termination, or origin ?

Nothing more than that there is no known limit to the duration of the existence of inorganic bodies, as such ; that, if compound, they may be chemically decomposed ; and that, by the chemical combination of their elements, new compounds may be formed.

Does any remark suggest itself as to the form of minerals on the one hand, and of plants and animals on the other?

Though minerals do, many of them, present certain definite polyhedral or many-sided figures, called *crystalline*, they may equally exist as shapeless masses; a particular form not appearing to be essential to them. The proper form of a plant or animal, on the contrary—as well of its component parts as of its body as a whole—is a necessary condition of its existence: as necessary a condition as the matter of which it is composed. In short, matter and form, it has been remarked, are two conditions which must concur to complete the idea of a vegetable or animal organism.

Is there anything to be said in regard to the relative sizes of plants and animals on the one hand, and of minerals on the other?

Variable as is the size of plants and animals, each species appears to be subjected to a limit in its growth, beyond which it cannot pass. The size of minerals, on the contrary, is unlimited. The same mineral may exist in the state of a minute fragment or as a mountain mass.

But what do you say of the extensive deposits consisting of the shells of infusory animalcules—of the whole mountain masses formed of the foraminated shells called *nummulites*, of limestone entirely composed of which, some of the Egyptian pyramids are built;—but especially of coral islands and reefs?

That they are the remains not of single animals, but the accumulated remains of whole races; and what is worthy of

note is, that they are the remains too of the minutest and most simple animals—viz., protozoa and polypi.

In regard to chemical composition, what difference is there between organized and inorganic bodies?

Of the chemical elements or bodies as yet undecomposed by chemists, but a small number has been found entering into the composition of plants and animals; and of that small number, a very few only appear to be proper constituents of organized substance. Such are especially oxygen, hydrogen, carbon, and nitrogen or azote. No chemical element, it is to be observed, enters into the composition of the bodies of plants or animals, which does not also exist in that of some mineral. The great difference, in respect to chemical composition, between organized and inorganic bodies, consists in the mode in which their elements are combined.

Describe the character of the chemical composition of inorganic bodies.

Inorganic bodies occur in the state of simple uncombined elements, such as gold, sulphur, &c., as well as in combination. When minerals are compound, their elements are combined in twos; and these binary combinations may be simple or double. Thus oxygen and carbon, united, form carbonic acid gas; and hydrogen and nitrogen, ammonia. These are simple binary combinations. But when carbonic acid gas and ammonia, united, form carbonate of ammonia, we have a double binary combination.

Describe the character of the chemical composition of organic bodies.

Into the composition of vegetable and animal substances there always enter three or more chemical elements ; and these are united each equally with all the others, forming ternary and quaternary combinations. Thus oxygen, carbon, and hydrogen, or these three elements with the addition of nitrogen or azote, in combination, each equally with all the others form the principal substances which constitute the basis of the organized structures of plants and animals. Thus fat, starch, sugar, woody matter, &c., are examples of ternary—albumen or white of egg, flesh, glue, &c., of quaternary—compounds. It is further to be remarked, that the atoms of ternary or quaternary compounds contain each a great number of atoms of the several elements which enter into their composition ; and as the numerous atoms of the several elements combine in various proportions, a large number of different compounds are formed out of the four different elements—oxygen, carbon, hydrogen, and nitrogen.

Inorganic compounds admit of being decomposed by ultimate analysis, and again formed by a recombination of their elements. How is it with regard to organic bodies ?

Organic principles are equally capable of being decomposed, but, with the exception of some of the more simple, cannot be recomposed by any of the ordinary processes of the laboratory ; organic combinations being the product of that subtle kind of chemistry only which goes on in living beings. Thus, for example, albumen or white of egg, or fibrine or flesh, may be resolved by ultimate analysis into carbon, oxygen, hydrogen, and nitrogen ; but when these elements are made to combine in the laboratory, instead of reconstituting albumen or fibrine, they form only some such double binary compound as carbonate of ammonia.

Are the ultimate elements of organized structures held together by strong affinities?

No. As it was under the influence of life they were first united, so it is principally during life that they continue in ternary and quaternary combination. When life ceases, decomposition commences. The elements separate, and, entering into new and more simple combinations, form among themselves, or with additions derived from the surrounding atmosphere, the inorganic compounds water, carbonic acid gas, and ammonia.

SECTION II. — ORGANIZATION AND LIFE OF PLANTS AND ANIMALS COMPARED.

In what respects do plants and animals, the two great divisions of organized and living beings, agree?

They are equally characterized by the faculties they possess of being nourished, and of reproducing their like.

In what respects are they distinguished from each other?

The difference between a bird and the tree on which it is perched is evident enough; but if we descend from the higher to the lower grades of either division, we come to a point where the two organic kingdoms seem to run into each other.

State what can be said in regard to the question

of a distinction between the lowest vegetable and animal organisms.

There are single-cell animal as well as single-cell vegetable organisms. Both appear to be destitute of sensibility, and the movements which the former may exhibit are not without a parallel among the latter. For example: the spores or germ-cells of the lowest algæ swim about in the water, like animalcules, by the action of vibratile cilia or minute hairlike filaments projecting from the surface of their body, which, like so many fins constantly in motion, propel it through the water. The chemical composition of these lowest vegetable forms, in their free moving state, does not appear to differ from that of animals, the substance of both being of albuminous nature. By and by, however, the spores lose their cilia and become surrounded by an investment of cellulose—a substance of the same chemical nature as woody fibre.

Describe the difference between plants and animals above the very lowest.

Animals above the very lowest are endowed with the faculties of sensation and muscular motion—faculties by means of which they are enabled to keep up an active intercourse with the external world. Plants, on the contrary, high as well as low, are totally destitute of any such faculties.

But do not some plants exhibit manifestations of sensibility, and execute very striking movements?

It is true that the leaf of the plant named “Venus’ fly trap” immediately folds upon itself, and encloses as in a trap the insect which may have set foot on the hairs growing on its surface; and everyone knows how the slightest touch causes the leaflets of the sensitive plant to fold together and the leaf-stalk to fall down. Such remarkable and interesting

movements do not appear however to be owing to nervo-muscular action, like the movements of animals, nor is the susceptibility to impressions a manifestation of real sensibility; for in the plants under notice there is not, any more than in other plants, either nervous or muscular system, the systems to which animals owe their faculties of sensation and motion.

The possession by animals of the nervous and muscular systems would alone render the animal more complex than the vegetable frame, but the exercise of the faculties of sensation and motion at the same time involves the complication of those functions which animals possess in common with plants. Hence it is that the bodies of animals are more complicated in structure than those of plants, not only by the organs of the faculties of sensation and motion, but also by the additional organs rendered necessary by the complication of the nutritive functions. Illustrate this proposition in detail.

Plants fixed in the soil directly absorb the matters which they require for aliment, and which are presented to their roots in a fluid or dissolved state, ready for absorption. The organs and functions of plants subservient to nutrition are therefore very simple. Animals, on the contrary, which are for the most part not rooted down to one particular spot, but possess the power of moving their body as a whole from one place to another—or at least, as is the case with polypi living on a solid stem, of moving certain organs for seizing their prey—have their nutritive organs and functions much more complex. First, they are provided with an internal cavity or stomach, into which they receive, occasionally, supplies of

food. The food thus received, different from the alimentary matters which are absorbed directly from the soil by plants, requires to be digested or dissolved before it is fit for absorption. This digestion or solution of the food is effected by the action of special juices in the stomach, which is thus not merely a storehouse for the food of the animal, but also a chemical laboratory. By the walls, or by vessels in the walls, of the digestive cavity—as by internal roots, to borrow the expression of Cuvier, the celebrated French naturalist—the nutritive part of the food, when thus digested or dissolved, is absorbed.

You have shown the existence of one capital distinction between plants and animals generally, viz., the possession by the latter of the faculties of sensation and nervo-muscular motion, together with a correspondingly more complex construction of body. Now, is there any other capital distinction?

Another capital distinction between plants and animals is found in a difference of character in the chemical action which goes on in their nutritive processes.

Explain yourself, first in regard to the chemical composition of vegetable and animal substances, somewhat in detail, in order that we may the better understand the difference in the character of the chemical action.

Oxygen, hydrogen, carbon, and azote or nitrogen, in ternary and quaternary combinations, we have seen, are the principal chemical elements of both vegetable and animal substances—ternary compounds of oxygen, hydrogen, and

carbon, in the forms of cellulose, starch, gum, sugar, oil, chiefly constituting the basis of the organized structure of plants; whilst animal structures more generally have for their basis quaternary compounds of oxygen, hydrogen, carbon and azote, in the forms of albumen, fibrine, caseine, and gelatine.

What is the name given to these ternary and quaternary compounds?

These ternary and quaternary compounds, as they constitute the materials of which the different tissues or structures of plants and animals are *proximately* or *immediately* composed, have been named *proximate organic principles*, in contradistinction to the elements oxygen, hydrogen, carbon, azote, &c., into which they are resolvable by ultimate analysis, and which are therefore named ultimate principles or elements.

Do not the proximate principles, albumen, fibrine, caseine, just stated to be those which animal structures more generally have for their basis, also exist in plants?

Yes. They are in fact vegetable products, and are, as well as such ternary compounds as are found in animal bodies, originally derived by animals from plants.

In more particular explanation of this, point out the difference between plants and animals in respect to the nature of their aliment.

Whilst plants assimilate and are nourished by inorganic matters, animals cannot assimilate inorganic matters, but require for their sustenance organic productions, both azotized.

and non-azotized, either in the form of vegetable substances (such as grains and fruits) or the flesh of other animals which have themselves been fed on vegetable substances.

Enumerate the inorganic matters which plants take in as aliment.

Water, carbonic acid gas, and ammonia, together with certain alkaline and earthy salts.

Whence are these matters derived?

The water, carbonic acid gas, and ammonia, are for the most part absorbed by the roots of the plant from the soil, and by the soil are derived principally from the atmosphere.

What changes do these inorganic or binary compounds, thus taken in as food, undergo, in order that they may be converted into the substance of the plant?

They are decomposed, and their elements oxygen, hydrogen, carbon, and azote, recombined so as to form ternary and quaternary compounds, azotized and non-azotized, which are converted into the solid structure of the plant or stored up in the cells of particular organs, primarily to serve some purpose in the economy of the plant itself, and eventually, it would seem, to provide a supply of food for animals.

Enumerate the vegetable substances which serve as food for animals.

In all plants, and in all their parts, used as food by animals, there is contained, dissolved in the sap, albumen, sometimes in greater, sometimes in smaller quantity. In the various kinds of grain there is a greater or less quantity of gluten or

vegetable fibrine. In beans, peas, lentils, there is contained legumenine or vegetable caseine—*i. e.*, cheesy matter. Still more common than these azotized quaternary compounds in plants are the non-azotized ternary compounds starch, gum, sugar, oil—for instance, starch in grains, potatoes, and other farinaceous products; sugar and gum in fruits, vegetables, &c.; oil in nuts, almonds, &c.—to say nothing of wine, beer, and spirits, prepared by fermentation from the saccharine principle.

The food of animals being, as you state, originally derived from plants—directly, as in the case of herbivorous animals; indirectly, as in the case of carnivorous animals, which prey on the herbivorous—may not plants be literally designated the preparers of food for animals?

Exactly so; for animals in fact can only incorporate with their structure organic principles, already prepared, but cannot themselves compound them out of inorganic matters.

How are the proximate principles composing the food of animals expended in the nourishment of their body?

The azotized proximate principles, in default of which for food animals die of hunger, merely take on a new form in the animal organism, without undergoing any essential change in chemical composition. The non-azotized proximate principles are not formed into tissues—do not serve for the nourishment of the body, properly speaking, for animals fed exclusively on them soon die of inanition—but they are expended in supplying materials for the respiratory process, and generation of the heat of the body. They are, in fact, so much fuel.

In what form do animals excrete the worn-out and decomposed old matters of their body?

In the form principally of water, carbonic acid gas, and ammoniacal salts.

Are not these the very matters which plants take in as food?

Yes.

What matter is it which plants give out to the atmosphere?

Oxygen.

Is not that the very material which animals take in from the atmosphere?

Yes.

To come now to the chemical action which goes on in the nutritive processes: might we not from this infer, *à priori*, that that action must be very different in plants and animals?

Such is the case.

Describe the chemical action which goes on in the nutritive processes of plants generally.

It is one of deoxidation, with a production of combustible substance. Thus, under the influence of the heat and light which the earth receives from the sun, the leaves and other green parts of plants, like apparatuses of reduction, decompose carbonic acid gas and water, retain the carbon and hydrogen, and give back the oxygen to the air. In this process heat is rendered latent.

Describe the chemical action which goes on in the nutritive processes of animals.

It is the converse of that in plants. The animal frame is an apparatus of combustion, in which the carbon and hydrogen contained in the matters consumed as food, and which we have seen are derived directly or indirectly from plants, are again oxidized, as in a furnace, by means of the oxygen taken in by breathing, and the product returned to the atmosphere in the form of carbonic acid gas and watery vapour. In this, as in other processes of oxidation, heat is disengaged.

In plants under certain circumstances, does not a similar process of oxidation, with disengagement of carbonic acid and heat, go on?

Yes; in the germination of seeds, as in malting. In the dark, also, oxygen is absorbed and carbonic acid gas given out.

Are oxygen, hydrogen, carbon and azote, the sole elementary constituents of vegetable and animal substances?

No; vegetable and animal substances, when burned, leave a certain quantity of ashes. These consist of alkaline and earthy salts, and are originally derived by plants from the soil in which they grow.

Are these alkaline and earthy salts necessary components of vegetable substance, or are they merely accidental?

They are so necessary, that their presence in the soil is an indispensable condition for the growth of the plants. Where

deficient, therefore, they must be supplied by manure before the plants can be reared.

Explain somewhat in detail the importance of alkaline and earthy salts, as constituents of vegetable and animal substances.

Plants cannot elaborate a grain of albumen or gluten out of the water, carbonic acid gas, and ammonia they take in, if they do not at the same time receive the due proportion of phosphatic salts. Nor can they form starch, sugar, &c., if alkaline salts be wanting. The slender stem of wheat, again, could not acquire sufficient firmness to support the ear, unless the soil yielded it the silica or flint which is found forming a hard enamel on the exterior surface of the hollow cylindrical stalk. The skeleton of animals, in like manner, would not be firm enough to support the frame, without the phosphate and carbonate of lime which enter so largely into the composition of the bones, and which is derived, directly or indirectly, through plants, from the soil.

SECTION III.—ORGANIZATION AND LIFE OF ANIMALS IN PARTICULAR.

§ *The Functions of Animals in their correspondence with each other.*

What do you mean by functions?

The actions performed by, and the processes which go on in, the organs of the body of living beings.

How are the functions of animals, so far as regards the economy of an individual, classed?

Under one or other of two heads, according as they are concerned : in the relations which the animal maintains with the external world, or in the preservation of the animal by nutrition.

Sum up the functions concerned in the relations which animals keep up with the external world.

Sensation and muscular motion, together with the mental acts of perceiving the sensations and willing and directing the movements.

Characterize sensation as it exists in the lowest animals therewith endowed.

It is extremely limited, consisting merely in tactile sensibility of the external integument of the body.

Indicate the development of the same faculty as we ascend in the animal scale.

It comprises several or all of the special senses of touch taste, smelling, hearing, vision—and these in greater or less perfection.

What have you to say of the mental faculties in animals?

That in the lowest animals, such faculties can scarcely be said to exist; but that in the higher animals they are developed in proportion to the number and acuteness of the senses.

And what of nervo-muscular motion?

As is the case with the senses and the mental faculties, so do we find that in the lowest animals nervo-muscular motion is circumscribed, but that by the higher animals it is enjoyed in the most varied perfection.

In regard to the degree of development in which sensation, mental faculties, and locomotion, are possessed by an animal, what remark suggests itself?

That it is in accordance with the number and variety of relations which the animal is destined to keep up with the external world.

What relation, if any, exists among the faculties in question, in respect to their degree of development?

The closest mutual relation, as will be at once recognized if we reflect on what would have been the condition of an animal endowed in a high degree with the faculty of sensation, without the power to move; or of an animal possessing the power to move, but destitute of sensation.

Does any such mutual and reciprocal dependence, like what you have stated to exist among the functions of relation, extend to the other classes of functions?

Yes; thus, whilst the degree of sensibility an animal is endowed with, and the activity of its locomotion, are in intimate mutual relation, they, in their turn, influence the means by which nutrition is accomplished.

Explain yourself more in detail.

The higher animals, for example, endowed with sensibility in an exquisite degree, and along with it possessing the power to move freely from one place to another in order to react on the surrounding objects, have their nutritive functions very complicated; but in the lowest animals (the

polyp, for instance, whose sensibility is limited, confined to the tactile endowments of its skin—and which is fixed to one spot, incapable of any other movement but that of its tentacula in the seizure of its food), nutrition is comparatively a very simple process.

Does there not exist also a relation among the functions of nutrition themselves, in respect to their degree of development?

Yes.

Give an illustration.

In the lowest animals, the absorption of alimentary matters and the absorption of oxygen in respiration are not localized in distinct organs, but higher in the scale we find this to be the case; and in order to bring the blood and air into contact with each other, particular provision is made. Thus, the air is, either, by a modification of the respiratory organ, conveyed (as in insects) to every part of the body, in order to mingle with the nutritive juices or blood dispersed through it; or the blood is conveyed (as is the case in most animals) to the circumscribed organ of respiration (a lung or gill, according to the mode in which the oxygen is to be supplied to it—whether in atmospherical air as such, or in air dissolved in water), in order to meet the air. For this purpose of conveying the nutritive juices to the respiratory organ to meet the air, and for the purpose of distributing the blood formed by the admixture of the nutritive juices and oxygen to the various parts of the body, in order that it may minister to their nutrition and to secretion, there is superadded the function of circulation.

§ *Connection between Structure and Function.*

In accordance with the degree of activity of the

functions throughout the animal series, there is a corresponding degree of development of the organs. Illustrate this proposition by examples.

The nervous system, the seat of the mental faculties (when such exist), and the centre to which sensations are communicated, and from which motor power issues, presents itself, in accordance with the activity of the relative functions, in various degrees of development: from the single ganglion or nervous centre, receiving and giving off nervous fibres of molluscoids—to the very complex nervous system of man, consisting of spinal marrow and brain, the great central organ to which proceed the nerves from the organs of sense, and from which the nerves to the various muscular parts of the body are given off. In like manner, the organs of sense are found in various degrees of development—*e. g.*, organs of touch, from the simplest sensitive tentacle to that organ of organs, the human hand; organs of sight, from the coloured eyedot of a monocolus to the far-seeing eye of the eagle. As is also the system of organs subservient to motion—from the case in which muscular fibres and the skin constitute the whole locomotive apparatus, to the case in which there are hard parts forming the skeleton or framework of the body, external or internal, and serving as levers to be moved by the contractile force of the muscles.

The less the extent to which the complication of structure and function is carried, the less is the individualization of the animal—the less the dependence of all the parts of the body on each other. Illustrate this proposition.

An animal (such as the polyp, for instance) whose body is of the same simple structure throughout, and each part of which performs a similar function and is independent of the

rest, may be cut in pieces in any direction, and yet each piece will live and become developed into a new polyp.

The greater the extent, on the contrary, to which the complication of structure and function is carried, the greater is the individualization of the animal—the greater the dependence of all the parts of the body on each other. Illustrate this proposition.

Life in the higher animals is so dependent on the concurrence of numerous different functions and their organs, that if the body be divided, the separate parts cannot continue to live, but either both segments die, or only that part lives which still retains the vital centres or organs of the functions essential to life—such as the brain and spinal marrow, the heart, the stomach.

§ *Unity of Organic Composition.*

Is there, in accordance with the varied manner, irrespective of activity, in which the functions throughout the animal series are performed, a corresponding variation of plan in the organization?

Yes; but in this variation we may trace a uniformity of design. Thus, in the organization of animals—of the members of any given division of the animal kingdom, especially—certain fundamental materials appear to be employed, which are variously modified, transformed, combined, or even omitted, to suit the conditions of existence of particular animals.

Give an example, drawn from a comparison of the arms and hands of man, the wings of bats and birds, &c.

Of the similar fundamental materials which compose our arms and hands, the wings of bats are, by one kind of modification, formed—viz., by the elongation of the fingers and the weblike extension of skin between them, as also between the arms and legs, and between the latter and the tail. By a somewhat similar modification, the wings, or rather parachutes, of the pterodactyle or extinct flying lizard, were formed. By a different kind of modification of the same materials, the wings of birds are constructed—viz., the retrenchment of the finger bones to such a form as to constitute a basis for the support of the feathers or elongated dermal or skin appendages of the animal, and pivots on which they may be spread out in a fanlike manner. By still different modifications of the same fundamental materials, the paddles of whales and the pectoral fins of fishes are composed.

But, on the other hand, may not a similar function be performed by fundamentally different organs?

Yes; the act of prehension or seizing performed by our hand, and the sense of touch principally seated in it, have in the elephant the proboscis for their organs, which is, fundamentally, merely a much elongated and modified external nose.

Again, an organ performing an important function in certain animals may not be called into requisition at all in others; the function being, in these, performed by a fundamentally different organ. Illustrate this proposition.

The lungs, the organs of respiration in mammiferous animals, birds, and reptiles, are not called into requisition in fishes, but the function of respiration is performed in these

animals by fundamentally different organs, viz., the gills—which, though thus *analogous* to, are *not homologous* with, the lungs.

Is there no organ, or trace of an organ, corresponding to or homologous with the lungs, to be met with in fishes?

Such does exist in an undeveloped state, but performing a subsidiary, different, or at least much modified function—viz., the air or swimming bladder.

Do we find, in mammiferous animals, birds, and reptiles, generally, in the perfectly grown state, analogous rudiments of gills?

No; but if we go back to the early period of development, when animals differ less and less from each other in structure, we shall discover rudimentary indications of gills in what are called the branchial arches of the embryo—a structure which, as one of the fundamental materials of the organization, had mingled or taken its place, as it were, with the rudiments of the other structures, but which soon disappeared by amalgamation with neighbouring parts.

Is there not an exception to this in the frog tribe?

Yes; the young of these reptiles, on emerging from the egg, breathe by gills, and have the organization and habits of fishes; but, by and by, the pisciform is replaced by the reptilian structure and habits. The swimming bladder becomes developed into lungs, and the gills shrink and disappear. Along with these changes in structure and modification of function, others occur, by which the animal becomes less exclusively aquatic in its habits. Moreover, in some of

the same tribe of reptiles—the proteus, syren, &c.—the very extraordinary peculiarity is met with, viz., persistence of the gills, although the lungs become developed. In such cases, we have a curious combination of the pisciform and reptilian characters. In one instance, in particular, that of the *lepidosiren*, the two kinds of characters are indeed so blended—the animal has advanced so little beyond the pisciform tadpole state—that a difference of opinion has existed, whether the lepidosiren be really a fish with the swimming bladder presenting a pulmonary development, as in some fishes, or whether it be really a batrachian reptile—*i.e.*, an animal of the frog tribe.

CHAPTER I.

NUTRITIVE PROCESSES OF THE HUMAN BODY.

SECTION I.—THE BLOOD, CIRCULATION,
RESPIRATION, &c.§ *The Blood.*

What are the constituents of the blood in respect to form?

The blood, as it circulates in the living body, is a liquid containing in suspension microscopical corpuscles.

State the chemical composition of the liquid.

The liquid part of the blood, commonly named *plasma*, consists of water holding in solution a large quantity of *protein* or albuminous principle, in the forms of albumen—properly so called—and fibrine (the latter in less quantity than the former), fatty matters, and various alkaline and earthy salts, together with colouring matter and certain other principles.

Describe the corpuscles which are contained suspended in the plasma.

Some, the majority, are red, like biconcave lenses in shape, and about $\frac{1}{3300}$ th of an inch in diameter. These red corpus-

cles to which the blood owes its colour (the plasma, or liquid in which they are suspended, being but slightly tinged yellow), are of the nature of free nuclei. The other corpuscles of the blood, which are colourless and few in number, are nucleated cells.

State the chemical composition of the blood corpuscles.

Their chief chemical constituent, called *globuline*, is an albuminous principle. Their red colouring matter, called *hematine*, is also a principle of allied nature in combination with iron, which metal, though a necessary constituent of the corpuscles, does not appear to be, as was once supposed, the cause of the red colour.

To what is the coagulation or clotting of the blood, which takes place after its escape from the living body, owing?

To the spontaneous consolidation of the fibrine contained in solution in the plasma.

What purpose does the blood serve in the economy?

It is the medium of the process of nutritive interchange, the constituents of the decomposed old matters of the body being received into it, preparatory to their eventual elimination from the system; whilst from it, the new matters, required to replace the old, are derived. The blood, thus a mixture at once of the matters of recomposition and decomposition, circulates through the body, in order that the various organs may abstract from it what they require for their nutrition and reparation, or what is necessary should be separated and expelled from the body as useless.

Which part of the blood is it that is immediately expended in the processes of nutrition and secretion?

The plasma.

What, then, appears to be the function of the blood corpuscles?

There is reason to believe that they are the vital excitants of the organs, and the agents by which the elaboration, necessary for maintaining the proper composition of the plasma itself, is effected. In consequence of their minuteness, they are fitted for the most complete reciprocal action with the plasma and the gases which it holds in solution.

§ *Mechanism of the Circulation.*

How is the circulation of the blood carried on?

By a hydraulic apparatus consisting of the heart and blood-vessels—viz., arteries, veins, and capillaries.

Describe the heart's action.

The heart is a hollow muscular organ, which, by its contractile power, propels the blood into the arterial tubes leading from it; and which, during its state of relaxation, succeeding contraction, is refilled with the blood brought back to it by the veins.

Explain yourself a little more in detail.

The interior of the heart is partitioned off into four compartments—an auricle and a ventricle, communicating with each other by a valvular opening, on the right side; and an auricle and a ventricle, communicating in a similar manner,

on the left. The auricles receive the blood from the veins—the right auricle, from the veins of the body in general; the left, from the veins of the lungs. By the simultaneous contraction of the auricles, the blood is transmitted into the ventricles—the blood from the right auricle into the right ventricle, and that from the left auricle into the left ventricle. The ventricles, having thus become distended with blood, now simultaneously contract, and propel the blood into their respective arterial trunks—the right ventricle, the blood into the pulmonary artery; the left ventricle, the blood into the aorta. During the contraction of the ventricles, regurgitation back into the auricles is prevented by the interposed auriculo-ventricular valves; whilst, after the contraction of the ventricles, regurgitation into them is opposed by the semi-lunar valves at the origin of the arterial trunks.

Describe the capillaries.

They are extremely minute vessels—called *capillary*, indeed, from their more than hairlike minuteness—interposed between the last ramifications of the arteries and the rootlets of the veins. Their average width corresponds to the diameter of the blood corpuscles; but, though individually so minute, their aggregate capacity is, on account of their immense number, much greater than that of the arteries leading to them, or of the veins leading from them.

What part do the capillaries play in the circulation of the blood?

They are passive, so far as regards the propulsion of the blood; but it is in flowing through them, which it does more slowly than in the arteries or veins, in consequence of their great aggregate capacity, that the blood gives out or receives back, through their delicate permeable walls, the matters in nutrition, secretion, and respiration. By the subdivision of

the mass of blood into minute streams in the capillaries, this process of interchange is not only much facilitated, but could not otherwise be effected.

Explain the part which the arteries play in the circulation of the blood.

The arteries, by the continuous contraction and elastic reaction of their walls, press on the column of blood, propelled into them by the heart, so as to force it on in its course; at the same time converting the intermittent flow, imparted to the blood by the rhythmical or intermittent action of the heart, first into a remittent, and eventually into the continuous stream which it presents in the capillaries. Regurgitation of blood back into the heart is prevented by the semi-lunar valves at the origin of the two great arterial trunks before referred to.

What purpose do the veins serve in the circulation of the blood?

They receive the blood from the capillaries and convey it back to the heart. At intervals in their course, in certain parts of the body—the legs and arms, for example—valves occur, in order that any retrograde movement of the blood may be opposed. The continuous contractility and elasticity of veins are small in comparison with the similar endowments of the arteries; the former, therefore, exert comparatively little pressure on the returning column of blood.

From what you have said, then, it would appear that in the circulation of the blood, the capillaries are passive—that the arteries supply no new force of their own, but, merely by their tonic contractility and elasticity, continue and modify that exerted

by the heart, serving a purpose analogous to that served by the air in the reservoir of a fire engine; and that the veins likewise supply no new force of their own, and but little of the modifying contractile and elastic power like what the arteries exert. But may it not be asked, if the power of the heart really be sufficient for the whole circulation?

In the opinion of many physiologists, the power of the heart is insufficient for the whole circulation, and various hypothetical auxiliary forces have been suggested. Of these, the most favourite has been one, undefined or variously defined, by the operation of which the flow of blood in the capillaries, it is conjectured, must be promoted. The truth, however, appears to be, that no special additional force is required, except in one particular instance, so far as regards mammiferous animals.

What is the additional force you refer to?

The rhythmical or pulsating contractility, like that of the heart, with which the veins of the bat's wing have been discovered* to be endowed.

How is it that the contractions of the veins, in this case, do not drive the blood backwards instead of forwards?

Because the veins are, at intervals, provided with valves which prevent regurgitation.

What remark does the discovery of the auxiliary force you have mentioned suggest?

* By the Author of this Catechism (see Phil. Trans., 1852).

That when, from some peculiarity, such as the great extent of the wing in comparison to the size of the heart of the bat, an auxiliary force is really required, such is called into existence by endowing the walls of the veins with rhythmical contractility—a contrivance simple and effective in comparison with those previously conjectured to be in operation.

How is the supply of blood to any given part regulated, increased, or diminished—seeing that the force of the heart must, as a rule, bear equally on the blood in the vessels of all parts of the body?

By dilatation of the small arteries of an organ, the flow of blood to it is rendered freer and more copious; whilst by constriction of the small arteries, on the contrary, the quantity of blood admitted to an organ is diminished.

How is the dilatation or constriction of the small arteries effected?

By the relaxation or contraction of their muscular walls.

How was Harvey led to the discovery of the circulation of the blood?

By reflecting on the well known facts—1, that the valves of the heart and blood vessels are so disposed as to permit the blood to flow in one particular direction only; 2, that the blood does actually flow in the arteries *from* the heart, as is seen by the direction of the jet from a cut artery; and 3, that the blood does actually flow in the veins *towards* the heart, as is evident in the operation of blood-letting.

What point in the demonstration of the circulation of the blood did Harvey leave undetermined?

The passage of the blood through the capillaries, from the extremities of the arteries, into the radicles of the veins.

Who discovered this additional demonstration?

Malpighi (a distinguished Italian physiologist, who flourished during the latter half of the 17th century, the early part of which had witnessed Harvey's brilliant addition to physiology), by calling the microscope to his aid, demonstrated the passage of the blood through the capillaries in the transparent parts of the living frog.

§ *Effete Matters eliminated from the Blood.*

Under what forms are the effete matters eliminated from the blood?

Principally under the forms of water, urea, and carbonic acid gas.

How and by what organs is the water eliminated?

In the form of the watery vapour in the breath from the lungs, in that of the perspiration from the skin, and in that of the urine from the kidneys.

What is urea?

A highly azotized compound, the product of the disintegration of the worn-out azotized structures of the body, such as muscle and sinew, in the nutritive process.

How is it eliminated?

In the urine, of which it is the characteristic solid constituent, being secreted by the kidneys as fast as it is formed in the blood.

§ *Animal Heat.*

Under what circumstances is the carbonic acid gas generated in the body?

It is formed by the combination, in the course of the nutritive process throughout the body, of the carbon of the old matters with the oxygen received by the blood from the air in breathing—a combination chemically identical with that which takes place in combustion.

Is heat disengaged by this combustion?

As in other cases of combustion, heat is disengaged, and is that which principally maintains the proper temperature of our body.

How and by what means is the carbonic acid gas eliminated?

Principally by the lungs, in respiration or breathing.

§ *Respiration or Breathing.*

What is the medium by which respiration is carried on?

The atmospherical air.

State the composition of atmospherical air.

Atmospherical air is a mixture of oxygen and azote or nitrogen gases in the proportion of about one of the former to four of the latter, together with a minute quantity of carbonic acid gas and more or less watery vapour.

Describe the mechanism of respiration or breathing.

In respiration or breathing, air is, by the muscular movements of the chest, alternately drawn in and expelled from the lungs: by diffusion of the pure inspired air into that already in the air cells of the lungs, the latter is always preserved of the necessary standard of purity. The blood circulating in the capillary vessels distributed in the walls of the air cells of the lungs receives the oxygen from this air, and at the same time becomes freed from the carbonic acid gas—a result of the combustion before referred to—with which it had become loaded in passing through the capillaries of the system. The carbonic gas, together with watery vapour, which is at the same time given out from the blood, is expelled in the expired air.

How does the blood receive the oxygen from the air in the air cells of the lungs?

By a process of liquid diffusion through the delicate walls of the capillary vessels in which it is circulating, the oxygen being dissolved in the moisture which bedews the inner surface of the air cells.

How is the carbonic acid gas given out from the blood to the air in the air cells?

By a similar process of diffusion, the carbonic acid gas being in a state of solution.

What essentially constitutes the object of the function of respiration?

The purification of the blood, by the excretion of carbonic acid gas and the absorption of oxygen instead.

Does the azote or nitrogen of the air play any part in the respiratory process?

It appears not to do so, but to serve merely as a diluent of the oxygen.

Describe the general characters of the blood before undergoing this process of purification.

It is of a dark red hue, and unfitted to maintain the energies of life—unfitted for the purposes of nutrition.

Describe the general characters of the blood after it has undergone the process of purification.

It is of a bright scarlet colour, and is the proper vital excitant of the organs, and the source whence are immediately derived the materials for nutrition, and secretion also, with the exception of that of the bile.

State the differences, in respect to composition, between the pure bright red blood and the impure dark red blood.

The bright red blood (named *arterial*, on account of its being principally contained in the arteries of the system) differs from the dark red blood (which is named *venous*, from its being principally contained in the veins of the system) chiefly by holding in solution more oxygen but less carbonic acid gas, and by containing more fibrine but fewer red corpuscles.

When the air we breathe contains a large quantity of carbonic acid gas, as it does in ill ventilated apartments where many people are congregated, or

where a great number of lights are burning, what is the effect on the system?

The blood is not properly purified, on account of the carbonic acid gas not being duly excreted from it, and for want of the necessary supply of oxygen. The consequence is, we feel ill; and if we continue to live in the impure air, the health becomes seriously injured.

If the quantity of carbonic acid gas with which the air is mixed be greater, as when the vapour of burning charcoal accumulates in an apartment, what is the result of breathing it?

Asphyxia and death.

How is this brought about?

The blood, being no longer purified, ceases to flow freely through the capillaries of the lungs; and, at last, its circulation is altogether arrested.

Is carbonic acid gas the only impurity with which the atmospherical air may be contaminated?

It is not. Dangerous as an undue admixture of carbonic acid gas in the air we breathe is, there are still more dangerous, because more insidious, impurities, with which it may be contaminated.

Of what nature are the impurities you refer to?

They are miasmatic poisons, arising and accumulating from neglect of cleanliness, drainage, and ventilation.

How do they act?

Diffused in the air we breathe, they are absorbed into

the blood, contaminate it, and either quickly give rise to fevers, &c., or, operating with less intensity and more slowly, so deteriorate the health as to render the body subject to disease from the slightest cause.

§ *The Blood in its Circulation through the Body.*

Trace now, in a summary manner, and in conclusion of this part of our subject, a given quantity of the blood in its circulation or course through the body.

The bright scarlet or arterial blood flows from the lungs, by the pulmonary veins, to the left auricle of the heart, whence it is transmitted into the left ventricle, and by that propelled through the aorta and its ramifications, the arteries, to the capillaries of the system. Here, as has been said, it serves the purposes of nutrition and secretion. Now become dark red or venous, and no longer fit for those purposes, the blood is received from the capillaries into the veins, and by them carried to the right auricle of the heart, by which it is propelled into the right ventricle. This, then, taking up the ball, drives the blood to the lungs, that, in the capillary vessels of the air cells of these organs, it may be freed from a portion of the carbonic acid gas with which it is now overloaded, and that it may acquire oxygen instead, and be thus again converted into the bright scarlet or arterial blood.

§ *Secretion.*

Define the function of secretion.

The separation, by the organs called glands, of certain matters from the blood, intended either to be expelled from the

body as excrementitious and useless, or to serve some purpose in the economy—the matters separated being elaborated by a process of cell development.

Enumerate some of the principal glands, and their secretions.

The mammary glands, and the milk ; the lacrymal glands, and the tears ; the salivary glands, and the saliva ; the gastric glands, and the gastric juice ; the liver, and bile ; the pancreas, and pancreatic juice ; the kidneys, and urine ; &c.

SECTION II.—THE FOOD, DIGESTION, ABSORPTION, &c.

By the constant abstraction of matters from the blood for the purposes of nutrition and secretion, this fluid would soon be exhausted if not occasionally replenished. Now, how are new supplies provided?

In the form of food and drink, to the enjoyment of which we are impelled by the appetites of hunger and thirst.

Draw a parallel between the functions of respiration and digestion in respect to the replenishment of the blood.

As by the function of respiration the blood is supplied with its essential gaseous element, oxygen, so, by digestion, it is replenished with its alimentary constituents.

§ *Mastication and Insalivation.*

Describe the process of mastication or chewing, and that of insalivation or admixture of the food with the saliva.

The food is first taken into the mouth, where it is masticated and insalivated—masticated or mechanically subdivided by the action of the jaws with their armature of teeth, in order that it may be the more easily acted on by the digestive juices; insalivated or mixed with the saliva, which is poured into the mouth at the time by the salivary glands, in order that it may be formed into a morsel fit for being swallowed, as well as that it may be chemically acted on.

§ *Deglutition.*

Describe the act of deglutition, or swallowing of the morsel.

The morsel of food, having been thus prepared, is transmitted, by the act of swallowing, into the stomach—a mechanism of automatic or involuntary movements in the throat being called into operation, to force it down the gullet, and at the same moment to close the entrance into the posterior nostrils on the one hand, and that into the windpipe on the other, lest the morsel might escape from the pharynx or back part of the throat into either of these passages, instead of pursuing its natural course downwards to the stomach along the œsophagus or gullet.

§ *Chymification.*

Describe the process of chymification or digestion in the stomach.

The food is reduced to a pulpy mass called *chyme*, by digestion in the gastric juice, which is secreted by small glands in the mucous membrane of the stomach. This juice is an acid fluid, combined with a peculiar organic principle named *pepsine*, which, in the manner of a ferment, promotes the action of the acid on the food at the temperature of the stomach, at which the acid alone would have been incapable of accomplishing the purpose.

§ *Intestinal Digestion.*

The food having been digested into chyme, what takes place next?

The chyme is, by the contractions of the muscular walls of the stomach, transferred into the duodenum or first compartment of the intestinal canal, whereinto by its presence it excites the flow of the bile, pancreatic and intestinal juices, from their respective glands, viz., the liver, pancreas, and intestinal glands. By the action of these juices the chyme is further digested, and its nutritive part separated and fitted for absorption.

§ *Chylification and Absorption of the nutritive part of the Food.*

Where is the absorption of the nutritive part of the food carried on?

In the course of the passage of the alimentary mass along the intestine, a passage which is effected by the peristaltic or wormlike contractions of the muscular walls of the canal.

What becomes of the nutritious part of the food, when absorbed?

It is carried away in order to be mingled with and converted into the blood.

Describe the process of absorption.

The absorption from the intestinal canal of the nutritious part of the food—or, as it is now called, the *chyle*—takes place by a process of imbibition, accompanied by cell development, analogous to secretion, into particular vessels called *chyli-ferous* or *lacteal*, which have their rootlets in the villi or small prominences, like the pile of velvet, on the surface of the mucous membrane lining the canal. The superficial extent of the absorbing surface, it may be mentioned, is increased by the elevation of the mucous membrane in transverse plaits or folds, named *valvula conniventes*.

Whither do the chyliferous or lacteal vessels convey the chyle?

To the *thoracic duct*.

What is the thoracic duct?

The vascular trunk (chiefly situated in the thorax or chest, whence its name), which, in addition to the chyle from the lacteal vessels, receives the *lymph* from the *lymphatic* vessels.

§ *Lymphatic Absorption.*

What is the lymph?

A fluid of a composition somewhat similar to that of the blood, only diluted, consisting of the matters left over from the nutritive interchange in the structures of the body, which are absorbed by the lymphatic vessels in a manner somewhat similar to that in which the chyle is absorbed by the lacteal vessels.

Where have the lymphatic vessels their origin?

On the surface and in the interstices of most parts of the body.

You have said that the lymph from the lymphatics, as well as the chyle from the lacteals, is poured into the thoracic duct, which in fact is the common trunk of these two sets of vessels. Whither, now, it is to be asked, does the thoracic duct convey the mingled chyle and lymph?

To one of the large veins near the heart, where they are mixed with the venous blood, as it pursues its course to the lungs to undergo the change into arterial blood already described.

With what peculiar organs are the lacteal and lymphatic vessels connected in their course, before opening into the thoracic duct?

The lymphatic glands, wherein the chyle and lymph undergo some elaboration.

By what force are the chyle and lymph propelled onwards in their respective vessels to the thoracic duct, and thence to the vein into which that trunk opens?

By the tonic or continuous contraction of the walls of the vessels themselves, aided by valves, which, like those of the veins, prevent a retrograde movement.

Is there nothing like a heart for the propulsion of the lymph?

Not in the human body, but in certain of the lower animals, there is such—in the frog, for example, there are four lymph hearts.

§ *Absorption by Capillaries.*

After the discovery of the lacteal and lymphatic vessels, they were supposed to be the sole agents of absorption. Is this opinion still considered valid?

No. Physiologists are now agreed that absorption by capillary blood-vessels takes place also; though it is of a different character from that by the lacteals and lymphatics.

State the difference between the two kinds of absorption.

Absorption by the capillary blood-vessels is a simple process of endosmose or liquid diffusion through the walls of the vessels; and the matters absorbed are weak solutions, miscible of course with the blood. Absorption by the lacteals and lymphatics, on the contrary, appears to be a process depending on cell formation, and analogous to secretion; the matters absorbed being such as are fitted to constitute a blastema or germinal substance, in which cells may be developed—viz., albuminous and fatty matters. Accordingly, the watery parts and weak saline solutions contained in the food are absorbed by the blood-vessels of the walls of the stomach and intestine, while the nutritive parts are absorbed, as before stated, by the lacteals.

§ *Composition of the Food.*

What is the chemical composition of the food,

as compared with the blood which it has to replenish ; and what the chemical composition of the blood, as compared with the body which it has to nourish ?

Similar. The constituents common to our food, our blood, and the substance of our body, are the azotized albuminous, and the non-azotized saccharo-oleaginous proximate principles, together with alkaline and earthy salts.

Describe the chemical composition of milk, the nutriment provided by nature for the young of mammiferous animals.

Milk is composed of the albuminous principle, in the form of caseine or cheesy matter—the saccharine principle, in the form of lactine or sugar of milk—the oleaginous principle, in the form of butter—with alkaline and earthy salts in solution.

How is the milk produced ?

Of the substance of the mother, milk is secreted by the mammary glands from her blood ; her blood is replenished by her food ; and her food, whatever be its form—whether consisting of vegetable or animal substances—is found to contain essentially the same principles as those just enumerated as entering into the composition of the milk.

It would thus appear, that it is chiefly by successive changes of form that the food is converted into blood, and blood into the substance of the body ?

Exactly so.

How are these metamorphoses, as also such chemical changes as do occur, effected?

By the processes of cell life.

The nutrition of the body, then, to which the mechanism of the interchained functions, circulation, respiration, digestion, &c., is subservient, when traced through all its different phases and modifications, reveals itself at last as essentially a process of cell life?

Yes.

SECTION III.—THE ANIMAL CELL.

§ *Structure and Development of a Cell.*

Describe the animal cell.

Like the vegetable cell, the animal cell is a microscopical vesicle, with a nucleus or smaller vesicle inside, together with a matter named primordial cell substance, which is sometimes granular, sometimes uniform in appearance.

Out of what, and how, are nucleated cells formed?

Nucleated cells are formed out of a material originally derived, directly or indirectly, from pre-existing cells. From this material, which is called *blastema* or *germinal substance*, and which is of albuminous or fibrinous composition (being, in fact, the plasma of the blood exuded from the blood-vessels), a deposit of organizable matter takes place, which collects into

small roundish masses. In the interior of these masses a nucleus is developed; while, by the consolidation of the exterior substance, the cell wall is formed. The remaining part of the primordial cell substance constitutes the contents of the cell thus produced. This development of cells may take place free in the blastema or in the interior of pre-existing cells, the contents of the latter serving as a blastema.

Is the cell wall the essential part of the structure of a cell?

Notwithstanding the name, it is not; for in certain cases a cell wall may never be formed. The primordial cell substance and nucleus appear to be the essential parts.

What is the nature of the property or force by virtue of which the materials are thus combined to form a cell; and by which the cell, when formed, maintains itself and undergoes its metamorphoses?

A cell, in its construction, presents, as before observed, the most simple example of organization; whilst in its nutrition, development, and varied metamorphoses, we have the most general and simple manifestation of life. The property or force, therefore, by virtue of which the materials are combined to form a cell, and by which the cell, when formed, maintains itself and undergoes its metamorphoses, we designate *vital*.

§ *Osmose.*

But in the actions of the organized and living cell, have we not physical properties or forces ministering to the purely vital?

Yes.

Which of the physical properties especially claims

some notice here, from its bearing on the processes of cell life?

Porosity of the cell wall, permitting of the process of osmose.

Describe the process of osmose.

Though two different but miscible fluids are separated by an intervening membrane, their diffusion into each other is not prevented: on the contrary, the two fluids pass through the pores of the membrane towards each other, and thereby become mixed together. Thus, if a dilute solution of sulphate potash and distilled water be the two fluids, they will become diffused into each other, the saline solution passing through the membrane to the water; the water, on the other hand, passing through the membrane to the saline solution. But it is to be observed, that a greater quantity of water passes through the membrane to mix with the saline solution, than there does of saline solution through the membrane to mix with the water. The result is, that the quantity of fluid in the compartment containing the saline solution is increased, and the saline solution diluted, while the quantity in the compartment containing the water is diminished; but, at the same time, the water, which before was pure, has become saline, by an admixture of some of the potash solution with it.

In the instance you have just adduced, it is the less dense fluid which is diffused in greater quantity into the more dense. Is it always so?

No; the opposite may be the case. Thus, when alcohol, which is less dense than water, is substituted for the saline solution, the water will be diffused in greater quantity into the alcohol than the alcohol into the water. On the other hand, if a vegetable acid, which is more dense than water, be substituted, it will be diffused in greater quantity into the water than the water into the acid.

What is the cause of these differences?

It appears to consist, in a great measure, in the readiness with which the animal membrane imbibes the respective fluids. It imbibes, for example, the water more readily than the alcohol, but the vegetable acid more readily than the water.

If, in the experiment with the vegetable acid and the water, you substitute a vegetable membrane for the animal one, is there any difference in the result?

Yes. The water will pass in greater quantity into the acid compartment, than the acid will into the water compartment; the vegetable membrane more readily imbibing water than acid.

It would thus appear, in short, that with different fluids or with different intervening membranes, different osmotic effects take place?

Exactly so.

Give examples of the operation of osmose in the economy.

The physical process of osmose, now described, besides being that on which depends the passage of matters out from and into the blood in the capillaries, in the process of nutrition, plays an important part in cell development; matters from and to the surrounding blastema being received into and given out from the interior of the cell, through the pores of its wall.

How is it that different kinds of cells and tissues take up and appropriate different matters from the same blastema, and, of course, are metamorphosed

and nourished each in its own way? and how is it that a renewal or change of the blastema will influence the process?

On the nature of the cell wall, depend very much the quality and quantity of the matters which pass from the surrounding blastema into the interior of the cell to be diffused into its contents, and *vice versâ*. On the other hand, the cell continuing the same, the nature of the matters which shall be received into it will vary with the nature of the surrounding blastema.

§ *Process of Secretion.*

Show how what you have said of osmose and cell development is applicable to the explanation of the process of secretion.

A gland, in its simplest form, is a small vesicle or tubule, in the interior of which are contained the secretory corpuscles or cells, with the blastema in and out of which they are formed. The fluid remains of the blastema and the secretory cells, now more or less broken up and disintegrated, constitute the secreted fluid which is poured out from the vesicle or tubule on the surface of the skin or mucous membrane to which the gland belongs.

Whence, and how, is the blastema, out of which the secreted fluid is thus elaborated, received by the glandular vesicle or tubule?

From the blood; and, as the principal chemical constituents of secreted fluids pre-exist in the blood, it probably depends on the peculiar quality of the membrane composing the walls of the constituent vesicles or tubules of each gland, as also of the membrane forming the walls of the capillaries

thereto distributed, that peculiar matters are received from the blood—different membranes producing, as we have seen, different osmotic effects.

To what is the appearance, in secreted fluids, of such compounds as do not already exist in the blood, owing?

In the process of cell development within the gland, as in other cases of the like kind, chemical reactions occur and new combinations result.

§ *Metamorphosis of Cells into Tissues.*

The constituents, in respect to form, of an organic fluid, such as the blood, lymph, secretions, are cells in different stages of development, but still separate corpuscles, suspended in a liquid. Now, point out the resemblance and difference between the structure of such a fluid and a tissue of the simplest kind.

A tissue of the simplest kind—of which we have examples in the epidermis or external cuticle, the epithelium or internal cuticle, &c.—is composed of cells held together by intercellular substance as by a cement, but still distinct corpuscles, though they may be more or less metamorphosed. Such a tissue, therefore, resembles an organic fluid in having similar constituents, and differs from it only inasmuch as the intercellular substance which holds the cells together is firm; whilst, in the organic fluid, the part which corresponds to the intercellular substance is liquid.

But are all tissues thus formed of cells, or of metamorphosed cells?

This question requires a qualified answer. It may be said that some tissues are not formed from fully developed cells, but that the primordial cell substance (as the deposit from the blastema is called) becomes at once moulded into fibres, &c., the phase of fully formed cell never being attained. In some such cases, the nuclei shrink and disappear; in others, they undergo metamorphosis, along with that of the cells or of the primordial cell substance.

The intercellular substance—the remains of the blastema, in and out of which the cells were formed—we have seen, constitutes the uniting medium of the cells or the bodies into which they have been metamorphosed. Now, what changes, if any, may it undergo?

The intercellular substance may continue a homogeneous-looking matter, or it may become granular or even fibrous; examples of all of which changes are presented by the intercellular substance which forms so large a constituent of cartilage or gristle.

Sum up the fundamental elements, in respect to form, which, from what you have now said, appear to enter into the composition of every tissue.

They may be stated to be three in number, viz.—1, the cell or body formed by its metamorphosis, or by the metamorphosis of primordial cell-substance; 2, the nucleus or body formed by its metamorphosis; 3, the intercellular substance.

§ *Endowments of the Tissues.*

Though the elements, in respect to form, composing the tissues, are thus fundamentally homo-

logous in their origin, do they not differ from each other, in their fully developed state, not only in form but also in endowments?

They do.

Explain the nature of the endowments of the tissues.

The organs of the body are composed of the different tissues, much in the same manner that a garment is made up of different kinds of cloth—woollen, cotton, and silk. Now, as woollen, cotton, and silk cloths have each of them certain properties peculiar to itself, so the tissues composing the organs of the living body have their peculiar properties; not only, however, the common physical properties, such as the just-mentioned kinds of cloth may present, but also other properties characteristic of their living state, and therefore named *vital*.

Considering, then, that of the different tissues each possesses peculiar properties, both physical and vital, may we not infer that, according to the particular tissues which enter into the structure of an organ, so will be the action of that organ?

Yes. Thus, while one organ (a sinew or ligament of a joint) serves as a passive cord, another (a bone) as a rigid lever, a third (the yellow elastic ligaments) possesses the physical property of elasticity, a fourth (a muscle) is the agent of motion—being endowed with the vital property of contractility, a fifth (a motor nerve) is the communicator of the stimulus of that property of contractility, a sixth (a sensitive nerve) is the conductor of sensibility, a seventh (the grey or ganglionic nervous substance) is the seat or centre of nervous action.

The elements, in respect to form, being of microscopical minuteness, must be comprised in great numbers in the structure of any given tissue?

Such is the case. The smallest piece of epithelium, bone, muscle, or nerve, for example, which we can dispose under the microscope, contains each a great number of its elements: a puncture of almost any part of the body with a fine needle brings the blood, by wounding capillary vessels; and in that blood, how small soever the drop, the corpuscles are seen under the microscope in great numbers. From this, some idea may be formed of the immensity of the number of cells aggregated together in the epithelia, of laminæ and corpuscles in the bones, fleshy fibres in the muscles, nerve fibres and ganglionic corpuscles in the brain and nerves—of capillary channels throughout the body, by which the blood, with its millions innumerable of corpuscles, is distributed to the various organs.

Give some illustration of the advantage of this great minuteness of the elements of structure.

The corpuscles of the blood, we have seen, are, in consequence of their minuteness, fitted for the most complete reciprocal action with the liquid in which they are suspended, and with the gases dissolved in it; whilst, by the division of the mass of blood into minute streams in the capillaries, the process of interchange of matters in nutrition and respiration is rendered possible. Again: a tendon or sinew, being composed of bundles of microscopical filaments arranged side by side and held together by interfibrous substance and cellular tissue, is much stronger and more flexible than it would have been had it been a homogeneous cord of the same substance and thickness.

CHAPTER II.

THE NERVOUS SYSTEM.

WHAT are the chief agents concerned in the exercise of the faculties of sensation and motion—the faculties whereby animals are enabled to perceive, and, by various independent actions, to maintain relations with the world around them?

Nerve and muscle.

But nervous and muscular action is not confined to the exercise of those faculties?

True. Nervous and muscular action is called into play, we have seen, in the circulation of the blood through the body, in the respiratory movements, the movements to which the food is subjected in the digestive canal, &c.

SECTION I.—ELEMENTARY CONSTITUENTS OF NERVOUS STRUCTURE.

What are the elementary constituents, in respect to form, of the substance of the brain and nerves?

Fibres and ganglionic corpuscles of microscopical minuteness.

Describe the fibres.

They are composed of a delicate tubular sheath, containing

a clear semi-fluid viscid substance, with a very delicate filament in its axis.

Describe the ganglionic corpuscles.

The ganglionic corpuscles are enclosed in dilatations of the tubules just described, are usually of a rounded or oval form, and have the appearance of nucleated cells. Their substance consists of a soft coherent matter, tinged with pigment, in which the nucleus, with its nucleolus, is imbedded.

What is the chemical composition of nervous substance?

Nervous substance is chiefly composed of albumen, and certain fatty matters, with some sulphur, phosphorus, &c.

Indicate the general character of the physiological endowments of these elements of nervous structure.

It may be laid down as a proposition, that the ganglionic corpuscles are centres of nervous action, and that the tubular fibres are conductors or communicators between them and the organs under their influence.

How are the nervous elements you have now described combined in the construction of the nervous system?

A nervous system, whatever may be its form in other respects, comprises central and peripheral organs—the central organs, composed of masses of ganglionic corpuscles with the central extremities of the nerve fibres in connection with them, forming ganglions or a spinal marrow and brain; the peripheral organs, composed of the nerve fibres collected into bundles called nerves, which are distributed, like a system of telegraphic wires, to the different parts of the body.

SECTION II.—PERIPHERAL ORGANS OF THE
NERVOUS SYSTEM, OR THE NERVES.

§ *Centripetal Nervous Action.*

Of what organs or structures of the body is sensibility the exclusive endowment?

Of certain nerves, as long as they are in connection with the brain. That all other parts of the body are sensible only by virtue of the nerves distributed in them, is a physiological fact now well known and established.

Give a proof of the fact.

The insensibility of a limb which results from section of its nerves.

How does the section of nerves produce this result?

By destroying the continuity of the nerves with the brain, and thereby interrupting centripetal nervous action or the transmission of impressions to the sensorium.

Do the parts supplied by the nerve above the place of section still retain their sensibility?

Yes.

Explain why.

Because, the nerves above the section being still in continuity with the brain, centripetal nervous action from them is uninterrupted.

§ *Centrifugal Nervous Action.*

You have said that the sensibility of a limb is lost after section of its nerves. Does any other effect follow?

At the same time that a limb is, by the section of its nerves, rendered insensible, its muscles are paralyzed—the will having no longer any power over them.

If the cut end of the segment of the nerve, no longer in connection with the brain, be irritated, no sensation is experienced; but is not some other effect called forth?

Although, on irritating the further end of the cut nerve, no sensation is excited, contractions of the muscles to which the nerve is distributed are called forth.

§ *Sensitive and Motor Nerves.*

It would thus appear that the nerves are conductors from the sensitive organs of the body to the central organ of the nervous system, and back from the latter to the muscles. The question now arises, how do we know that the conduction in these two opposite directions does not take place by the same path?

Taking into consideration the fact that the face is supplied with nerves from two very different sources, the late Sir Charles Bell came to the conclusion that the two nerves probably differed from each other in their physiological endowments. To put this to the test, he cut one of the two nerves

(viz., a branch of the fifth pair) in one animal, and the other nerve (viz., the "hard portion" of the seventh) in another animal, and watched the results. These he found, in the two cases, such as to warrant the conclusion that, by the section of the fifth nerve, sensation only was abolished, whilst, by the section of the hard portion of the seventh nerve, motor power only was interrupted—that, in short, nervous conduction was, in the face, effected *from* the skin *to* the nervous centre, by one nerve; and *from* the nervous centre *to* the muscles, by another nerve—that the fifth nerve in the face was exclusively the sensitive or centripetal nerve; the hard portion of the seventh, exclusively the motor or centrifugal nerve.

What application did Sir Charles Bell make of these results, in explanation of the conduction of sensation and motion by the nerves of the limbs?

Having thus explained how it is that the face may on one side be paralysed without being insensible, and how, on the other hand, it might be insensible without being bereft of motion, Sir Charles Bell applied himself to the investigation as to how a leg or arm may be paralytic without being insensible, and *vice versâ*: in other words, to determine whether there were distinct sensitive or centripetal nerves, and distinct motor or centrifugal nerves distributed to it.

How was this investigation carried out?

Physiology had already shown, as we have before seen, that the result of section of one of the nerves of the limbs is the loss of both sensation and voluntary motion of the parts below the section; and anatomical examination had demonstrated that the nerves, at their origin from the spinal marrow, have two roots. Now, it occurred to Sir C. Bell that the spinal nerves might possibly be composed of both sensitive

and motor nervous fibres bound up together; and further, that of the two roots, one might consist exclusively of the motor fibrils, and the other exclusively of the sensitive fibrils.

How was this put to the test?

Sir Charles Bell, having had an animal rendered insensible by a blow on the head, laid bare the spinal marrow, with the roots of the nerves arising from it. He then irritated the anterior and posterior roots separately, and found that the irritation of the anterior root only was followed by well marked contractions of the muscles to which the nerve was distributed. From this it was evident that the anterior roots of the spinal nerves consist solely of motor fibrils like the hard portion of the seventh nerve of the face; and the inference was, that the posterior roots consist solely of sensitive fibrils like the larger portion of the fifth nerve. Between the larger division of the fifth nerve and the posterior roots of the spinal nerves there was moreover the anatomical resemblance, that they both present ganglionic enlargements; whilst the smaller division of the fifth, not before referred to, which is composed of motor fibrils distributed to the muscles of the jaw, presents, like the anterior or motor roots of the spinal nerves, no ganglionic enlargements.

What doctrine did these discoveries of Sir Charles Bell thus fully establish?

That some nervous fibrils have for their exclusive functions the conveyance of impressions made on what are called sensitive parts to the brain, and which communicate no motor influence to muscles; whilst, on the contrary, other nervous fibrils have for their exclusive function the conveyance of motor influence to muscles from the nervous centre, and are wholly insensible.

Are there any nerves composed exclusively of sensitive fibrils?

Yes; the nerves of the three higher senses—viz., the optic, auditory, and olfactory.

Are there any nerves composed wholly of motor fibrils?

Yes; the nerves of the muscles of the eye, face, &c.

In the case of nerves in which both sensitive and motor fibrils are bound up together, does the aggregation exert any influence on the functions of the respective fibrils?

It does not appear to do so, but is a mere anatomical arrangement.

Cannot adjacent nerve fibrils communicate directly a state of excitement to each other?

It would appear not. It is only through the medium of their ganglionic centres that nerve fibrils can react on each other.

SECTION III.—CENTRAL ORGAN OF THE NERVOUS SYSTEM.

§ *Spinal Marrow.*

What is the spinal marrow?

The spinal marrow—or, more correctly, the spinal cord—is a part of the central organ of the nervous system.

Where is it situated?

In the canal of the vertebral column, or backbone.

Why has it been named spinal marrow?

From a false analogy with the marrow in the interior of the long bones.

Describe the structure of the spinal cord.

It is composed of grey or ganglionic, and white or fibrous, nervous substance—the former disposed in a continuous track in the *interior*, like the pith; the latter composing the *exterior*, like the woody part of a twig.

What nerves issue from the spinal cord?

The spinal nerves, which are distributed principally to the skin and muscles of the trunk of the body and the limbs, and which, as already mentioned, are each composed of both sensitive and motor fibrils mingled together in one common fasciculus, except at the place where they join the spinal cord. Here, as we have seen, the sensitive fibrils are collected together in one root, the *posterior*; and the motor fibrils in another root, the *anterior*.

Indicate the function of the spinal cord.

The spinal cord is partly a conductor *to* and *from* the brain, and partly an independent nervous centre.

What does it conduct?

As a conductor, it communicates impressions of touch, from spinal nerves in the skin, to the sensorium; and transmits from the brain voluntary motor influence to the muscles, by the spinal nerves.

Which is the part of the spinal cord that acts as a conductor?

The white exterior fibrous substance, which is continuous on the one hand with the fibrils of the spinal nerves subservient to sensation and voluntary motion, and, on the other, is continued, as we shall see, into the sensorial ganglions of the encephalon or brain—the portion of the central organ contained within the skull.

Which is the part of the spinal cord that performs the function of an independent nervous centre?

The ganglionic substance, or grey pith, to and from which some of the fibrils of the spinal nerves have been shown to proceed, instead of remaining mixed up with those which are continued into the white exterior fibrous substance of the cord.

Considered as an independent centre, what actions does the spinal cord preside over?

The reflex muscular actions, as elucidated by the late Dr. Marshall Hall.

Mention an example of reflex action.

The wriggling movements exhibited by a water newt's tail containing the caudal portion of the spinal cord, recently detached from the animal, on pinching the skin.

What is the character of these movements?

These movements are purpose-like, as if intended to throw off the offending body; and yet it is quite clear that the tail, detached from the animal (which may be still living), can

possess no consciousness of any sensation nor power of instinctive action, properly so called, much less of voluntary action. It is also to be observed that the movements are not spontaneous, but take place only on the application of a stimulus to the skin. They never vary, but are always the same, like the movements of an automaton.

What proof is there that the movements you have described depend on the portion of the spinal cord within the canal of the caudal vertebræ?

If you thrust in a wire and destroy the portion of the spinal cord in question, movements of the tail no longer take place, however much the skin may be afterwards pinched.

Describe the mechanism of reflex action.

The impression made by pinching the skin is communicated by one set of centripetal nerve fibrils (named *incident*) to the ganglionic central portion of the spinal cord, whence motor influence is reflected by another set of centrifugal nerve fibrils (named *reflex*) to the muscles of the tail.

Give another example of reflex movements.

Purpose-like reflex movements of a still more remarkable character are exhibited by a decapitated frog. If the skin of the belly of an animal thus mutilated (and consequently incapable of feeling pain or perceiving any sensation whatever, and as incapable of any voluntary action) be irritated, the feet will be raised up to the place, and movements executed as if for the purpose of removing the offending agent.

Give an example of reflex movements in the human body.

If you tickle the sole of a person asleep, the leg will be drawn up.

§ *Medulla Oblongata.*

What is the medulla oblongata ?

The medulla oblongata may be viewed partly as a continuation upwards of the spinal cord, and as possessed of the same general structure and endowments ; and partly as a portion of the encephalon or brain, considered as the great sensorial centre.

Where is the medulla oblongata situated ?

Between the brain and spinal cord, with each of which it is continuous.

Of what movements is the grey or ganglionic substance in the interior of the medulla oblongata, considered as a continuation of the spinal cord, the reflex centre ?

The movements of respiration and deglutition.

Which are the nerves forming the communication between the medulla oblongata and the organs over the movements of which it presides ?

Parts of the three divisions of the eighth pair of nerves—viz., the pneumogastric, glossopharyngeal and spinal accessory, and parts of certain spinal nerves—viz., the phrenic and intercostal nerves.

Describe the mechanism of reflex action in the respiratory movements.

The portion of the pneumogastric nerves distributed to the lungs furnishes incident fibrils ; whilst the spinal accessory, phrenic and intercostal nerves, supply the reflex fibrils to the muscles of respiration.

Describe the mechanism of reflex action in the movements of deglutition.

The glossopharyngeal nerve supplies the incident, and the pharyngeal branch of the pneumogastric the reflex, fibrils.

What is the nature of the white nervous substance which forms the exterior of the medulla oblongata?

It is a continuation upwards of the fibres of the white exterior substance of the spinal cord, consisting of sensitive and motor fibrils.

Is there anything peculiar in the course of these fibres in the medulla oblongata?

They decussate—*i. e.*, intersect each other from one side to the other; the fibres forming the right half of the spinal cord coming to form the left half of the medulla oblongata, and contrariwise.

Can this decussation of fibres be directly observed?

Yes.

But how is its full extent known?

That the decussation is complete appears from the results of injury or disease. Thus injury or disease of the brain, on one side, above the place of decussation in the medulla oblongata, occasions paralysis of sensation and motion, and these effects are constantly manifested on the opposite side of the body; whereas, on the contrary, if the injury or disease implicate the spinal cord, below the decussation, on one side, in any part of its length, the paralysis of sensation and motion

of the parts below, which may result, is always manifested on the same side.

Indicate the function of the medulla oblongata, viewed as a portion of the encephalon or brain; the latter being considered as the great sensorial centre.

It is the seat of the ganglionic centres of the special nerves of hearing and taste.

§ *The Brain : comprising Cerebrum or Great Brain, and Cerebellum or Little Brain.*

The great central organ of the nervous system comprises the spinal cord, medulla oblongata, and brain. You have already described the structure and functions of the spinal cord and medulla oblongata. Now what have you to say in regard to the brain?

The brain is fundamentally composed of a series of ganglionic masses—the centre of sensations, and source of instinctive and voluntary movements.

Considered as the centre of common sensation and source of instinctive and voluntary motion, what are the connections of the brain?

In the first place, it receives and gives fibres from and to the spinal nerves, through the white fibrous substance of the spinal cord and medulla oblongata; and in the second place, it receives the nerves of common sensation of the face and neighbouring parts, and sends forth their corresponding *nerves of motion*.

Considered as the centre of the special sensations of sight and smelling, what have you further to observe of the brain?

That it comprises among its ganglionic masses the optic and olfactory ganglions, with which are connected respectively the central extremities of the optic and olfactory nerves.

To the series of ganglionic masses, of which the brain is fundamentally composed, what parts do we find superadded in gradually increasing development, as we ascend from fishes up to mammifera and man?

The hemispheres of the cerebrum or great brain, and of the cerebellum or little brain.

Describe the structure of the cerebral hemispheres.

They are composed exteriorly of grey or ganglionic substance; between which and the sensorial ganglionic centres, just spoken of, there is interposed white fibrous substance.

What appears to be the function of the cerebral hemispheres?

They appear to be the seat of the mental faculties.

Explain yourself a little on this point.

That the white fibrous substance interposed between the exterior grey or ganglionic substance of the cerebral hemispheres and the sensorial ganglionic centres directly conducts neither sensation nor motion, has been found both by experiment on the lower animals and by the observation of cases of injury and disease in man. The white fibrous substance in question appears to be the medium by which, in some manner,

an intercommunication takes place between the sensorial centres and the exterior grey or ganglionic substance of the cerebral hemispheres: this substance itself being, as is supposed, the seat of mental activity.

What evidence is there to indicate that the hemispheres of the brain constitute the seat of the mental faculties?

Facts in comparative anatomy, experiments on animals, and the results of injury and disease in man.

Instance the facts in comparative anatomy.

In the lowest vertebrate animals, in which there is little or no manifestation of intelligence—though they may, like invertebrate animals, evince great instinct—the hemispheres of the brain are very rudimentary. With increasing development of these parts, animals give increasing manifestation of intelligence; and high above all animals stands man, in respect to the development of his brain hemispheres on the one hand and his intelligence on the other.

Mention the experiments on animals you have referred to.

When the hemispheres of the brain have been removed, the animal subjected to the experiment has continued to live, even for some months, all the vital functions being duly performed; but quite deprived of intelligence, as if in a dream or in a state of stupor.

What is the result of injury or disease of the cerebral hemispheres which has been observed in *man*?

Various degrees of disturbance of the intellectual faculties, even to their annihilation.

Describe the structure and functions of the hemispheres of the cerebellum.

Like the hemispheres of the cerebrum or great brain, those of the cerebellum or little brain are composed of grey or ganglionic substance exteriorly, and white tubular or fibrous substance interiorly; and these substances appear also to possess psychical endowments, though of a different character from those of the cerebrum.

What appear to be the psychical or mental endowments of the cerebellum?

From experiment it would appear that, under the influence of the cerebellum, the voluntary movements of the body are harmonized, co-ordinated, and restrained; but that there is no actual source of voluntary power in the organ. Thus, when the cerebellum is removed from an animal, the power of walking, springing, flying, standing, or maintaining equilibrium, is said to be abolished. The animal, however, it is alleged, does not seem to have lost voluntary power over the muscles, but only to have lost the power of so combining their action as to effect a particular purpose.

What does phrenology say of the hemispheres of the cerebrum and cerebellum as the seat of the mental faculties?

Not only that the mental faculties have their seat therein, but also that each faculty has appropriated to it, as its organ, a distinct portion of the hemispheres, and that, according to the greater or less development of that portion, so is the person endowed with the faculty of which it is the organ in a greater or less degree.

But how is it that phrenologists profess, by examination of the skull, to ascertain the degree of development of the alleged organs of the mental faculties?

According to the degree of development of an organ of any of the faculties, so is it, they affirm, prominent on the surface of a particular region of the hemispheres; and as the skull is moulded on the brain, there is a corresponding prominence of the skull.

SECTION IV.—SYMPATHETIC NERVES.

Describe the sympathetic system of nerves.

The sympathetic is a system of ganglions dispersed throughout the head and trunk of the body, the nerves from which, by anastomosis with cerebral and spinal nerves, effect an interchange of fibrils, so that the cerebral and spinal nerves receive some of the sympathetic fibrils, and the sympathetic nerves some of the fibrils from the cerebral and spinal nerves.

To what parts are the sympathetic nerves principally distributed?

Principally to the organs of circulation, respiration, digestion, secretion, &c.

What is peculiar in regard to the sensibility of parts supplied by the sympathetic nerves?

Sensibility is slight or altogether absent. What sensibility there may be manifested appears due to such of the cerebral or spinal nerve fibres, intermixed with the proper sympathetic *nerve fibres*, as are continued up to the sensorial centres.

What is peculiar in regard to the movements of muscular parts supplied by the sympathetic?

They are involuntary.

What is the function of the ganglions of the sympathetic?

They are centres of action for their own proper fibrils—of which some are incident, others reflex.

Over what functions has the sympathetic nerve been supposed especially to preside?

Nutrition and secretion.

How does it act?

It appears to be by governing the contraction of the walls of the arteries, so as to vary their width, and thus regulate the supply of blood to a part. The sympathetic nervous system, there is reason to believe, does not exert any direct special influence on nutrition and secretion.

CHAPTER III.

MUSCULAR SYSTEM.

SECTION I.—STRUCTURE AND ENDOWMENTS OF MUSCLE.

§ *Elementary Constituents.*

What is muscle?

The flesh of the body.

Describe the structure of muscle.

Muscle is composed of bundles of peculiar microscopical fibres, arranged side by side, together with motor nerve fibres dispersed amongst them in regular order.

Indicate the peculiar character of muscular fibres.

The fibres of the muscles of the skeleton or ordinary flesh of the body are enclosed in delicate tubular sheaths, and their structure is such as to give them, when viewed under the microscope, a transversely striated appearance. The fibres of the muscular substance of the heart present a somewhat similar appearance under the microscope; but those of the muscular substance of other internal organs—the walls of *the stomach*, for example—are not striated, but dotted.

State the chemical composition of muscular substance.

Muscular substance is principally composed of a particular form of fibrine in the solid state.

§ *Contractility.*

What is the characteristic endowment of muscle?

Contractility—the vital property which its fibres possess of becoming, under a certain influence, contracted or shortened; and, on the cessation of that influence, relaxing, so as to resume their former length.

What purpose does muscular contraction serve?

Muscular contraction is the power by which all the great movements of animals are effected.

Indicate the influence under which muscles contract.

Motor nervous influence, which is communicated to them from the nervous centre by the motor nerves, which are distributed among their fibres.

How is the motor nervous influence supposed to act?

It is a question in physiology whether motor nervous influence excites contraction merely by calling into play an already inherent power of the muscular fibres—or whether the nervous influence acts by imparting a new condition to the muscular fibres, by virtue of which they acquire at the moment the power to contract, and this in a manner analogous to that in which soft iron is rendered magnetic by galvanism.

§ *Voluntary and Involuntary Muscular Action.*

We move at will. This is equivalent to saying that we contract our muscles at will. And this, again, is equivalent to saying that we transmit motor nervous influence to muscles at will. Muscles thus under the control of our will are named *voluntary*. Now, are there muscles not under the control of our will?

There are muscles which act independently of our will, and which are therefore named *involuntary*.

Instance the muscles, the action of which is voluntary—and those, the action of which is involuntary.

With the exception of the heart, the muscles composed of transversely striated fibres—that is, the muscles of the skeleton—ordinarily, though not always, contract at will; but over the contractions of the heart, and over the contractions of all the organs composed of non-striated fibres, such as the muscular walls of the stomach, the will has no direct control.

When speaking of reflex nervous action, we saw that muscles of the skeleton, which ordinarily contract at the instance of the will, are thrown into action on irritating the skin under circumstances when there can be no exertion of will. The mechanism of this involuntary action of voluntary muscles we saw to be as follows:—The impression made by irritating the skin is communicated by in-

cident nerve fibrils to the ganglionic central portion of the spinal marrow, whence motor influence is reflected by reflex nerve fibrils to the muscles. Now, is the involuntary action of involuntary muscles due in a similar manner to reflex nervous action?

Such is the case, though the phenomena of purely involuntary muscular action are in many respects peculiar.

Which system of nerves presides over the movements of the involuntary muscles?

The sympathetic system of nerves.

Besides their motor nerves, do voluntary muscles receive any sensitive nerves?

They do, and are thereby possessed of sensibility—according to some physiologists, a special sensibility—by which we are enabled to estimate the force of our muscular exertions.

SECTION II.—LOCOMOTION.

Describe the mechanism by which the contraction of the muscles effects the movements of the body.

The bones of the skeleton, and the apparatus of the joints, compose the machinery which is to be set in motion. The bones constitute a system of levers, movable on each other at the joints; and to these levers the muscles are attached through the medium of the tendons or sinews, which serve as cords to be drawn by the contraction of the muscles, so that

the levers may be moved on each other and the machinery set in play. For example: our limbs are apparatuses of bones, joints, sinews, and muscles, so arranged that by the contraction of such and such muscles, which we have the power of determining at will, the bones are alternately fixed and moved on each other; whence result the various acts of walking, running, &c.

When muscles are relaxed, how do they return to their former length, and how do the parts which had been approximated again recede from each other?

The parts which had, by muscular contraction, been approximated, are drawn away from each other again, either by elasticity or by the action of antagonistic muscles—that is, muscles so placed as to draw in a contrary direction.

§ *Short Leverage of the Bones.*

Is there any peculiarity in the leverage presented by the bones?

There is a peculiarity in that the arm of power is very short in comparison with the arm of resistance; whereas, in common mechanics, it is generally an object to obtain the arm of power as long as possible in comparison with the arm of resistance, for by this means the expenditure of less force is required.

What advantage is gained by this short leverage, to compensate for expenditure of power?

Extent and rapidity of motion are obtained, space economized, and symmetry preserved.

Explain how muscular power would have been inapplicable to long leverage, whilst, on the contrary, it is in strict adaptation to short leverage.

The contraction or shortening of a muscle in action is of limited extent; short leverage, therefore, was the only means of obtaining the requisite sweep of movement of the bones on each other. At the same time that the extent of shortening of the muscles is limited, the power with which they do contract is great; hence they are equal to all requirements, notwithstanding the disadvantageous leverage under which they have to act.

SECTION III.—VOICE AND SPEECH.

Besides having the power to move from one place to another and to perform innumerable other actions in obedience to the behests of the will, we possess the faculty of giving expression to our thoughts, and thus communicating with others by means of voice and speech. Describe the mechanism of voice and speech.

The organ of voice, called the *larynx*, constructed of cartilages, muscles, and membranes, is a reed instrument surmounting the trachea or windpipe. The performance of this instrument depends on the contraction of its muscles varying the size of the aperture through which the air from the lungs passes, and the tension of the vocal cords or membranous tongues. The various modifications of the voice constituting speech are produced by movements of the lips, tongue, palate, and throat.

CHAPTER IV.

THE SENSES.

Describe the fundamental construction of an organ of sense.

An organ of sense is, fundamentally, composed of a proper nerve, one extremity of which is connected with the brain, the other with a special apparatus placed at the surface of the body, viz.—the skin, for touch; the tongue, for taste; the nose, for smelling; the ear, for hearing; and the eye, for sight.

How does this special apparatus act?

It receives and transmits the external agent which is destined to make the impression on the nerve.

What part does the nerve play?

A part analogous to that of a telegraphic wire, inasmuch as it transmits to the brain at one end the impressions it receives at the other.

What purpose do the senses serve in the economy?

They are the inlets through which the mind takes cognizance of external objects.

What is the nature of the intelligence which is, in the first instance, communicated to the mind *through the senses*?

Sensations.

How are sensations resolved into the varied knowledge of external nature which we receive?

As in telegraphic communications a kind of shorthand is employed, so sensations may be viewed as the shorthand of the senses, to be read off by the mind at length.

SECTION I.—SENSE OF TOUCH.

Which are the nerves of the sense of touch?

The sensitive fibrils of the spinal and cerebral nerves, distributed to the skin.

Name and describe the parts with which the peripheral extremities of these nerve fibrils are connected.

The papillæ of the skin all over the body; peculiar microscopical corpuscles which they contain in their interior, together with the investing epidermis or cuticle, being the medium through which the impressions made by the contact of external bodies are transmitted to the nerves.

Though the skin generally is the seat of touch, is not a particular portion of it appropriated as the special organ of that sense?

Yes; the skin of the hand.

Describe the hand, considered as an apparatus subservient to the sense of touch.

Placed at the end of the arm, the hand possesses in it a long pedicle, capable of extension, flexion, abduction, adduction, circumduction, rotation, &c., whereby it may reach and be brought into contact with objects at some distance and in various directions. Moreover, the hand itself, as a whole, is capable of being moved on the forearm, at the wrist, by flexion, extension, adduction, and abduction; whilst, intrinsically, it is fitted to execute the most varied and delicate movements. In the human hand, in short, are concentrated all those peculiarities of construction necessary to enable us to mould it on the contours of the objects we wish to examine, to run it over their surface, to touch them on several points at once, and that with a degree of pressure infinitely varied.

What are the sensations peculiar to the sense of touch?

Heat and cold; together with the various modifications of what is known under the name of common sensation, including its extremes of pleasure and pain.

What information regarding external objects does the mind read off from these shorthand sensations?

Information regarding their form, size, consistence, roughness, smoothness, &c.

SECTION II.—SENSE OF TASTE.

What constitutes the apparatus with which the peripheral extremities of the nerves of taste are connected, and through which sapid impressions are transmitted?

The papillæ of the investing membrane of the tongue.

What sensational endowments do the papillæ of the point of the tongue possess?

A fine sense of touch, as well as sensibility to sweet, sour, and saline tastes.

What sensation do we more particularly refer to the back part of the tongue?

The sensation of flavour.

Whence do the papillæ of the investing membrane of these two different regions of the tongue receive their nerves?

From different sources; the point of the tongue being supplied from the fifth, or trifacial nerve; the back part, from the glossopharyngeal portion of the eighth.

How is a sapid body transmitted to the nervous papillæ?

By imbibition through their investing epithelium.

In what state, therefore, does the sapid body require to be, in order that it may make its impression?

In a state of solution.

In what manner is the muscular body of the tongue subservient to the sense of taste?

The muscular body of the tongue serves as an auxiliary to the proper organs of the sense of taste, by pressing the sapid

body between its surface and the palate, and otherwise in a manner generally analogous to that in which the hand serves as an auxiliary in the case of the sense of touch.

Besides being subservient to the sense of taste, does the tongue perform any other function?

Yes; it constitutes an indispensable part of the apparatus of speech, and is an auxiliary in the acts of mastication and deglutition.

What is the nature of the information which the mind can read off from the shorthand sensations of taste and flavour?

Information in regard to the quality of our food. And thus it is with obvious design that the organ of the sense is placed as a sentinel at the very threshold of the stomach.

Explain how the duties of sentinel are performed.

The tongue being an auxiliary in the act of mastication, both the tactile and gustatory sensibility of its investing membrane are in requisition during the performance of that act; the mind, through them, minutely scanning the qualities cognizable to touch and taste of every particle of the morsel.

SECTION III.—SENSE OF SMELLING.

Indicate the seat of the sense of smelling.

The membrane lining the cavity of the nostrils, in which the peripheral extremities of the olfactory nerves are distributed.

What purpose does the sense of smelling serve?

The sense of smelling concurs with that of taste in enabling us to appreciate the quality of our food; and also tests, in some degree, the purity of the air we breathe: the nose, therefore, at the same time that it is not far from the mouth, stands sentinel at the very entrance of the respiratory passages.

How are odoriferous particles received into the nostrils?

Suspended or dissolved in the air.

Being received into the nostrils, in what manner do the odoriferous particles come into contact with the extremities of the olfactory nerves?

They are dissolved in the moisture which bedews the surface of the olfactory membrane, and, in the state of solution, are transmitted to the nervous extremities, by imbibition through the investing epithelium of the membrane, in a manner similar to that in which sapid solutions are transmitted to the extremities of the gustatory nerves.

Is the lining membrane of the nostrils all equally the seat of the sense of smelling?

No. The sense of smelling is chiefly confined to the portion of the membrane lining the upper and back part of the cavity of the nostrils—that towards which the air, loaded with odoriferous effluvia, is drawn by the act of sniffing, and where the olfactory nerves are especially distributed.

With what kind of sensibility is the lining membrane in the lower part of the cavity, and towards the entrance of the nostrils, endowed?

Common sensibility merely.

To which nerve is this common sensibility owing?

To a branch of the fifth nerve—the same nerve as that on which the tactile sensibility of the point of the tongue depends.

What analogy may be herein perceived between the organs of taste and smelling?

In both, the membrane which is the seat of the sense is, towards the exterior, endowed with common rather than with special sensibility.

What appears to be the design of this arrangement?

That the common sensibility should serve as an outpost watch, to guard the specially endowed parts within. By a similar provision, it may be observed, the internal parts of the ear and eye are watched and guarded.

What constitutes the auxiliary apparatus of the proper organ of the sense of smelling—the apparatus by which the air, loaded with odoriferous effluvia, is sniffed into contact with the olfactory membrane?

The nostrils, as a part of the respiratory passages, together with the apparatus of the chest subservient to the respiratory movements.

SECTION IV.—SENSE OF HEARING.

How, and where, is the peripheral extremity of the auditory nerve disposed?

It is peculiarly expanded within the innermost cavities of the ear.

What kind of apparatus is the ear?

An acoustic apparatus; or an apparatus specially adapted for the transmission to the auditory nerve of sonorous undulations, which are the natural excitant of the sense of hearing.

What remark suggests itself on comparing the apparatus for the transmission of the external agent which is to make the impression on the auditory nerve, with those for the transmission of the proper excitants of the nerves of touch, taste, and smelling?

That the apparatus for the transmission of the proper excitant of the auditory nerve is much more complex; and that, moreover, the accessory part of the apparatus does not, as in those senses, minister to other functions, but is exclusively appropriated to the sense of hearing.

Describe the mode in which sound is transmitted to the auditory nerve.

The undulations or vibrations communicated by the sounding body to the air, falling on the auricle or external ear, are by it collected and transferred by reflection to the air of the auditory passage. By the undulations thus transmitted through the air of the auditory passage, the membrane of the

drum is thrown into vibration ; and the vibrating membrane, on its part, communicates a similar state to the *air* contained in the cavity of the drum. From this, undulations are propagated through the membrane of the cochlear fenestra of the bony labyrinth to the *perilymph*—a thin watery fluid contained in the labyrinthic cavity, and which surrounds the membranous apparatus lined by the peripheral expansion of the auditory nerve, called *membranous labyrinth*. Filled with a more viscid fluid, named *endolymph*, this nervo-membranous apparatus receives from the perilymph surrounding it the sonorous undulations which were communicated from the drum, through the cochlear fenestra of the bony labyrinth. *Calcareous concretions*, which the membranous labyrinth also contains, are supposed to impart to the expansions of the auditory nerve, in its interior, vibratory impulses of greater intensity than a simple liquid, like the endolymph, is considered alone calculated to do.

Is the mechanism of the ear fully understood in all its parts ?

No: of the particular use of certain parts of the labyrinth, nothing certain is known.

You have referred to air contained in the cavity of the drum, as the medium through which the sonorous undulations are propagated from the membrane of the drum to the labyrinth. Now, how does that air get into the cavity of the drum ?

Through the Eustachian tube, the passage by which the cavity of the drum communicates with the throat.

Besides air, is there anything else in the cavity of the drum ?

Yes. There is a chain of three small bones, jointed together, and movable on each other by the action of muscles.

With what parts are the two ends of this chain of ossicles connected?

One end is connected with the membrane of the drum; the other, with the membrane closing the vestibular fenestra—one of the openings leading from the cavity of the drum into the labyrinthine cavity.

Has this chain of ossicles not been supposed to be the principal medium by which the sonorous undulations are communicated from the membrane of the drum to the labyrinth?

Yes; but the mode of propagation through the air in the cavity of the drum, as above explained, there is reason to believe the more probable.

What, then, is the use of the chain of ossicles?

The chain of small bones, with the muscles moving them, appears rather to serve the purpose of bracing the membrane of the drum, the membrane of the vestibular fenestra, and, indirectly, that of the cochlear fenestra, together with the nervo-membraneous labyrinth, and so adjusting the organ for different degrees of sound.

What is the sensation peculiar to the nerves of hearing?

Sound, in its various modifications.

And what the information which the mind can read off therefrom, concerning the external objects

which, through the medium of sonorous undulations, excite it?

It is information regarding their vibratile qualities, their distance, their position, &c. But it is to be observed, that the mind often attaches itself more to the sounds themselves, as sounds; their conventional meaning, their quality and varied modulations, as in the case of speech and music, awakening ideas in the mind which bear little or not at all on the external sounding body.

Does the "musical ear" depend on any peculiar development of the organ of hearing, or is it a mental faculty?

It is a mental faculty.

Does the faculty of estimating the distance and direction whence sounds issue belong to the ear or to the mind?

The faculty has been attributed to certain parts of the ear; but it is undoubtedly an endowment of the mind alone, as much as the "musical ear."

Explain how.

By an original and connate endowment, the mind refers its perception of sound to without, and to some distance from the body. According to the intensity and other peculiarities of the sensation, and the manner in which it is necessary to turn the head in order to hear the sound most distinctly, so does the mind, guided by experience, judge of the distance and direction whence the sound emanates.

How does ventriloquism produce its startling *illusions*?

By imitating the peculiarities which characterize sounds issuing from this or that distance, this or that direction or place.

SECTION V.—SENSE OF SIGHT.

What is the name of the nerves of the sense of sight?

The optic nerves.

How is the peripheral extremity of the optic nerve connected with the eye?

It is expanded into the nervous membrane called *retina*, which lines the back part of the eyeball.

What kind of apparatus is it which the segment of the eyeball in front of the retina forms?

A dioptric apparatus, or system of lenses for the transmission of light.

What purpose does the light serve in vision?

It is the medium by which external objects make their impression on the retina, and thereby excite visual sensations.

In regard to the accessory parts of the eye, do they, like the accessory parts of the organs of touch, taste, and smelling, minister in part to other functions? or are they devoted to the sight alone, as the accessory parts of the ear are to the hearing?

They do not minister to other functions, but are devoted to the sight alone.

What is the form of the eyeballs?

They are of a globular form.

How are they placed and moved in their sockets?

The eyeballs lie so balanced, each in its socket, as to admit of being turned in all directions, within certain limits, by the action of their muscles, in order that they may be fixed on the various objects in the field of view.

What provision is there for the protection of the eyeballs?

The eyebrows and eyelids, together with the lacrymal apparatus, protect them from any ordinary external injury.

Without entering into any details regarding the optical theory of vision, trace the course of the light to the retina through the dioptric apparatus of the eye.

Like the lenses of a camera obscura, the ocular dioptric apparatus, as already observed, so refracts the rays of light which enter the eye, in a state of divergence from the several points of an external object, as to make them converge to points or foci. These points or foci of light impinge on the retina, as on the table of a camera obscura, in the same relative order as that in which the rays forming them originally diverged from the several points of the external object, and a picture is thus impressed on the retina.

Of all the dioptric parts of the eye, which contributes most to the convergence of the rays of *light*?

The cornea.

How can that be, when the crystalline lens is both double convex, and of greater refractive density?

The cornea contributes most to the convergence of the rays of light, because the rays enter it from the air, which is of so much less refractive density than the cornea.

Mention a fact which proves that the crystalline lens contributes comparatively little to the convergence of the rays of light.

After a successful operation for cataract, which consists in the removal from the eye of the crystalline lens which has become opaque, a person is still able to see objects without the assistance of glasses, though of course not so distinctly as with that assistance.

How is it that the crystalline lens, though double convex, and of such great refractive density that, out of the eye, it is a strong magnifier, contributes comparatively so little to the convergence of the rays of light within the eye?

Because the rays of light enter the crystalline lens from the aqueous humour, the refractive density of which is not so much exceeded by that of the crystalline lens as the refractive density of the air is by that of the cornea.

How is spherical aberration obviated in the eye?

By the elliptical and hyperbolical curvatures of the surfaces of the dioptric parts, by the diminishing density of the crystal-

line lens from its centre to its circumference, and by the stop or diaphragm which we have in the iris and pupil.

How is distastial aberration obviated?

By an ellipsoidal curvature of the retinal surface on which the images of external objects are projected, and by an adjusting power of the dioptric apparatus.

How is chromatic aberration obviated?

Probably by a difference in the relative refractive and dispersive powers of the cornea and humours of the eye.

If there had not been a convergent optical apparatus in front of the retina, but if that nervous expansion had been exposed to the impression of light equally all over its surface, what could we have seen?

Nothing but a uniformly luminous field.

There have been and are persons who pretend they can *see*—mark, *see*—to read with the fingers, the pit of the stomach, the back of the head, and the like. Now, is such an achievement possible?

If, with eyes destitute of optical apparatus, we could have perceived the presence of light only, but could not have recognized objects, it is evident that with the skin, which has no optical apparatus, it must be impossible to see objects, even supposing the nerves of the skin to be as susceptible to the impression of light as the optic nerves, which is not the case. It need scarcely be observed, that to distinguish by the touch raised letters, and even recognize the colour of objects by the grain of their surface, as the blind can do, is quite *another thing*.

§ *Vital Action of the Optic Nerves.*

Turning to the vital action of the optic nervous apparatus in the act of seeing, the first question that suggests itself is: What is the sensation peculiar to the optic nerves?

Light, in its various modifications of colour and tint.

What is the information which the mind can read off therefrom concerning the external objects which, through the medium of the luminous undulations, impress the retina?

It regards the form and size of the objects, their position, colour, &c.

In the exercise of the sense of sight, to where does the mind refer its perceptions?

To without, and to some distance from the body—to the place, in short, where the objects perceived are, and not to the retina on which the impression is actually made.

You have previously stated, that in the exercise of the sense of hearing, the mind also refers its sensations to without, and to some distance from the body. Now, what appears to be the design of this?

It is evident if we consider that we take cognizance of external objects, by the sense of hearing, only through the medium of sonorous undulations; and by the sense of vision, only through the medium of luminous undulations proceeding from the objects.

Do we take no cognizance of the fact that the impression exciting a visual sensation is actually made on the retina ; nor of the intervention of the impressing agent, light ?

The uninformed mind does not, because it knows nothing either of the retina or of luminous undulations.

Has it not been maintained that the visual perception of outness is dependent merely on experience and association acquired through the sense of touch ?

Yes, it has been so maintained by Bishop Berkley and many other metaphysicians ; but good and sufficient reasons can be given for believing that the visual perception of outness is altogether independent of experience, and is truly owing to an original connate law of the economy.

Is there any fact which might be adduced in support of this, by analogy, from the history of touch—the very sense which is relied on in favour of the opposite side of the question ?

Yes ; the well known fact that persons, who have had the misfortune to lose a leg or arm, sometimes feel as if the lost limb were still in connection with the body, and that some part of it, perhaps, is the seat of pain.

In conformity with the laws of light, the pictures of external objects, projected on the retina by the dioptric apparatus in front of it, are necessarily inverted. How is it that, notwithstanding this, we do not see the objects inverted ?

That we see objects upright, as they are, depends on the same original connate law of the economy as that on which our visual perception of outness depends—the law, namely, of visible direction; in obedience to which, the mind, in referring a sensation, excited by an impression on the retina, to without and to some distance from the eye, does so in a direction more or less nearly perpendicular to the surface of the retina at the point where the impression is made.

To the mind, the size of an object observed by the sense of touch corresponds to the extent of the surface of the skin impressed by it, and no more; but the mind's visual perceptions as regards size are different, for we see objects of a size greater than the extent of the retina impressed by their pictures projected on it. How is this?

The greatness of the apparent size of visible objects, in proportion to the extent of the retina impressed by their pictures, depends on the projection outwards of the mind's perception of the picture, and therefore comes under the law of visible direction.

How does single vision with two eyes admit of being explained?

When impressions are made on what are called corresponding or identical parts of the two retinae, as is necessarily the case when the two eyes are naturally directed to the object looked at, the two similar sensations resulting from the impressions are referred by the mind outwards to the same place. The image seen by the one eye thus coinciding with that seen by the other, the object appears single.

Is this a sufficient explanation of single vision with two eyes?

Not quite, as is evident from stereoscopic phenomena—namely, the amalgamation of two dissimilar perspective pictures into a single image in bold relief or *intaglio*, as the case may be, not exactly like either perspective.

The conditions for single vision with two eyes, then, are not only the correspondence of the two retinæ above referred to, but also a peculiar mental endowment?

Just so.

Explain how it is, as shown by the stereoscope, that by the combined action of the two eyes we are enabled to perceive the length, breadth, and thickness of objects.

Owing to the position of the two eyes in the head, each is fitted to receive on its retina a different perspective picture of the object, if situated within a certain distance, in a manner analogous to that in which, with two fingers, we can receive impressions from two sides of a solid body, so that we recognize its thickness as well as its length and breadth; whilst the mind, by virtue of its endowment just referred to, and which depends on an original connate law of the economy, does not perceive two superposed dissimilar images, but only a single one, and that, unlike either of the perspectives, in relief or *intaglio*, as the case may be.

What additional faculty is implied in that of perceiving the three dimensions of space?

The faculty of recognizing the distance and position of objects situated within certain limits.

When we consider the outness of visual per-

ceptions, erect vision though retinal impressions are inverted, the great size of visual appearances in comparison with the small extent of retina impressed, and single vision with two eyes, what reflection suggests itself?

That they are exemplifications of a provision by which the vital action of the optic nervous apparatus and the physical constitution of the eyes are adapted to each other, and both to external circumstances.

But have not erect vision though retinal impressions are inverted, the great size of visual appearances in comparison with the small extent of retina impressed, single vision with two eyes, and the visual perception of the three dimensions of space, as well as the outness of visual perceptions, been supposed to depend merely on experience and association, through the sense of touch?

Yes.

What appears to have been the origin of this mistaken supposition?

The assumption that the mind must, of necessity, originally refer the sensation to the part impressed in vision, as it does the sensations of touch to the point of the finger—an assumption which the slightest analysis of our powers of observation with sight and touch will show to be of the most gratuitous character.

SECTION VI.—AFTER-SENSATIONS.

What is meant by an after-sensation ?

The sensation which continues a short time after the impression which excited it has ceased to act on the organ of sense.

In which of all the senses is the retention of sensations most remarkable ?

Touch and sight ; especially the latter.

Give an example of the retention of visual sensation.

If we turn away the eyes from looking steadfastly at a window, we shall continue to see the window for nearly half a second.

If the eyes, when turned away from the window, be shut or directed to a black surface, what appearance, in respect to the lights and shadows, does the spectrum of the window present ?

The lights and shadows are the same as appeared at the time of regarding the window—viz., the panes light, and the bars dark.

If, on the contrary, the eyes be directed to a light surface, what appearance, in respect to the lights and shadows, does the spectrum of the window present ?

The reverse of what they presented when looking at the window—viz., the panes dark, and the bars light.

If the object from which the impression has been derived is coloured, what is the appearance of the spectrum in respect to colour?

It is slightly coloured also, but differently—thus : greenish if the object be red, orange-tinged if blue, violet-tinged if yellow, and *vice versâ*.

Explain why the colour of the spectrum is called *complementary*.

The colour of the spectrum is always that which, being added to the colour of the object looked at, makes up the sum of the three primitive colours yellow, red, and blue, which, by their combination, form white light: hence the name *complementary* which has been given to the colour of the spectrum.*

* For further details regarding sight, see the Author's work on "The Wisdom and Beneficence of the Almighty, as displayed in the Sense of Vision." London: Churchill, 1851.

CHAPTER V.

MIND.

SECTION I.—PERCEPTION.

§ *Energies of the Nerves of Sense.*

You have said that the sensations excited by the impression of external objects on our organs of sense, constitute the sum of the knowledge which is in the first instance communicated to the mind through the senses: now, do these sensations represent any quality of the external object which makes the impression?

They do not; though we commonly argue as if they did.

On what, then, do the sensations immediately depend?

On the excitement of the peculiar energy of the nerves of sense.

What, then, does the external object communicate by its impression?

Simply the change of state of the nerves of sense, whereby their energy is called forth; and this being propagated to the *brain*, our mind perceives or becomes conscious of the sensa-

tion proper to the nerve of sense whose energy has been called forth.

Give some proof to show that the sensation does not represent any quality of the external object which makes the impression on the sense.

Contrast, for example, the *sensation, light*, and the *external agent, light*. The sensation which we experience in consequence of an impression on the eye, we denominate *light*; and the external agent, which commonly makes the impression, we also call *light*. But the sensation, and the external agent which by its impression on our eye excites in us the sensation, are totally different things. The external agent, light, considered in itself, is not clear, nor yellow, nor red, nor blue; it is merely the undulations, different in size and rapidity, of a universally distributed and excessively tenuous imponderable ether.

Give a proof that the sensation of light depends solely on the peculiar energy of the optic nerves, and not on the nature of the agent which impresses them.

The fact, that the sensation of light may be called forth by impressions on our eyes made by other external agents besides that which is specially called light. Thus everyone knows that if we press on the eyeball, as far back as possible, in the dark, we see a luminous spectrum before the eye, but on the side opposite to the spot where the pressure is applied. From this mechanical impression on the retina, no other sensation but that of light results; and if it were possible to apply more defined pressure on the retina, we should no doubt see a correspondingly more defined spectrum, as we indeed sometimes do of the blood vessels of the retina,

when, in consequence of undue congestion of blood in them, they cause pressure on that expansion of the optic nerve.

At a trial for assault in Germany some years ago, the ludicrous mistake was made of confounding the sensation of light, excited by a blow on the eye, with the agent light. Relate the case.

A clergyman was assaulted, one dark night, by two men, one of whom struck him on the right eye with a stone. By the light which streamed from his eye, in consequence of the blow, the clergyman averred that he was enabled to see and identify the man who committed the outrage. The question whether this was possible was actually raised in the criminal investigation, and the official district physician was referred to for his opinion. That gentleman, without fully admitting the possibility of what the clergyman maintained, still thought that there was some probability in it.

What experiment, has it been remarked, ought the district physician to have made, in order to have enabled himself to come to a more decided conclusion?

He ought to have given himself a blow on the eye in the dark, and tried to read by the light thereby emitted !

Though luminous undulations are thus not the sole agency by which the energy of the optic nerve may be called forth, do they not constitute the agency by which this is effected in the most intense degree and defined manner?

They do; they in fact constitute the agency, through the *medium of which* it has been appointed that external objects

should impress the retina. Accordingly, there is the dioptric apparatus of the eye fitted for the transmission of the luminous undulations, and for effecting the changes in their direction necessary for bringing the several pencils of light to foci on the retina.

While, through the medium of luminous undulations, external objects impress the retina, are the undulations themselves perceptible?

The effect of their impression on the retina is the sensation of light, but the undulating ether is itself too subtle to be seen.

Is what has now been said of the optic nerves and their sensations equally applicable to the other nerves of sense and their sensations?

Yes. To take, for example, the auditory nerves—the sensation excited in us by an impression on the ear, we call *sound*; and the external agency, which commonly causes the impression, we likewise call *sound*; but the *sensation*, and the *external agency* which by its impression on our ear excites in us the sensation, are, as in the case of the *sensation* of light and *agent* light, totally different things. The external agency, sound, considered in itself, is not melodious or harsh—it is merely the undulations or vibrations of the particles of surrounding bodies, propagated through the air by corresponding undulations of its particles, and thence, as we have seen, through the passages of the acoustic apparatus of the ear, to the auditory nerve.

Give a proof that the sensation of sound depends on the peculiar energy of the auditory nerve, and not on the nature of the agent which impresses it.

The fact, that the sensation of sound may be excited by a

box on the ear, or by pressure on the auditory nerve—the pressure arising from over-distension of the blood vessels, ramified in the expansion of the auditory nerve within the ear; just as the sensation of light may be excited by a blow on the eye or by pressure on the retina.

Though sonorous undulations are thus not the sole agency by which the energy of the auditory nerve may be called forth, do they not constitute that by which it is called forth in the most intense and defined manner?

They do; and are, in fact, the agency through the medium of which it has been appointed that external objects should impress the auditory nerve; accordingly, there is the acoustic apparatus in front of the expansion of the auditory nerve, fitted for the transmission of sonorous undulations.

§ *A Sixth Sense.*

For the sake of illustrating further what has been said regarding the powers of the senses, let us suppose we had a sixth sense. In such a case, what should we perceive by it?

All that we could, in the first instance, perceive, would be merely an additional peculiar sensation.

In order to call forth this sensation, must we suppose the excitant of the sense to be an agency unknown to us through the other senses?

Not necessarily: the sensation might be excited in us by impressions made on the nerve of the additional sense by objects already known to us by other sensations, through the medium of the other senses.

What then would the additional peculiar sensation perceived through the sixth sense teach, if merely called forth by the impression of objects already known?

From the peculiar sensation, the mind might be able to read off information regarding the object exciting it by its impression on the organ of the additional sense, or other information not deducible from the sensations excited by the same object impressing the other senses.

Still, might there not be a certain agency unknown to us through the other senses, and cognizable only through our supposed additional sense?

Certainly: there might be an agency fitted to excite the sensation peculiar to the additional sense, in the most intense and defined manner—and for the transmission of which to the nerve, the structure of the organ of the additional sense would be specially adapted.

Have we in reality a sixth sense?

We have no sixth sense. Some physiologists indeed admit, as we have before mentioned, what they call the muscular sense, by which, they suppose, we are enabled to estimate the force of our muscular exertions; but there can be little doubt that it is principally by the sense of touch that we do so.

Is there reason to believe that any of the lower animals are endowed with a sixth sense?

So far as is known, none of the lower animals possess such.

Give a general summary of results from our inquiries into the powers of the senses.

Each nerve of sense is capable of communicating to the mind one particular kind of sensation only, whatever be the nature of the agent which impresses it—though, according to the nature of the impression, that sensation may be variously modified; and thus the mind can read off various particulars regarding the external objects suggested by the modification of the sensations. One nerve of sense thus cannot really communicate the sensation of another: in short, we cannot hear with the eye nor see with the ear.

May not deaf and dumb persons learn to understand what is said to them by watching with the eye the movements of the lips, &c. of the speaker?

Yes; by interpreting the movements as they would the finger-alphabet or signals at a distance.

Again: are not blind persons sometimes able, in an analogous indirect manner, to determine, by means of the hearing, what can in reality be directly observed only by sight or touch?

Yes.

Might it not therefore be said that, in the one case, the deaf hear with the eye? and, in the other case, that the blind see with the ear?

It might be so said, but figuratively only.

SECTION II.—NATURE OF OUR KNOWLEDGE OF THE MATERIAL WORLD.

From the preceding considerations, what appears to be the answer to the question—What is the nature of the knowledge of the world around us which we acquire through the senses?

We can take no direct cognizance of external objects—we merely experience sensations, or signs of the impression of external objects on the senses. But the mind, by virtue of its peculiar innate powers, interprets those signs, and intuitively concludes as to the existence and qualities of the external objects which made the impression on the senses.

Though the changes in the state of the brain whereby we are rendered conscious of sensations are usually the result of the communication of changes in the state of the nerves of sense, induced by the impressions of external objects on them, may not such changes in the state of the brain be the result of changes in the state of the nerves of sense, induced by impressions made by some agency operating within them?

Yes.

May not such changes be also primarily induced by some cause directly operating within the brain itself?

Yes.

You mean to say, then, that there is no sensation

excited by the impression of external objects on our senses, which may not also be excited by some cause operating within the body: either within the nerves of sense themselves, or directly within the parts of the brain with which the central extremities of the nerves of sense are in connection—the parts of the brain which constitute their ganglionic centres?

Exactly so.

By what name are sensations excited by the impression of external objects on the senses distinguished?

Objective sensations.

And how are those, called forth by causes operating within the nerves or brain itself, designated?

Subjective sensations.

Give examples of subjective tactile sensations.

A sensation as if insects were creeping on the skin; neuralgic pains, &c.

Mention common examples of sounds heard independently of any impression from without.

ringing and buzzing in the ears.

As to subjective visual appearances, under what form do we sometimes see them?

In the form of flashes of light in the dark.

From this it appears, that even although our senses had never received an impression from without, we might still have had experience of sensations?

Quite so. Although a physical ray of light had never entered the eye, we might have had experience of the sensation of light; although a vibration from without had never struck the ear, we might still have had experience of the sensation of sound; although nothing had ever come into contact with the skin, we might have had experience of tactile sensations: and we all know that, independently of any special external impression, we have that common sensation throughout the body by which we are conscious of its existence.

How then can we know that external objects exist in the one instance and not in the other, seeing that, even in the case of what is called objective sensation, we can take cognizance of no more than we do in the case of subjective sensation—viz., a sensation?

Though a sensation is all that we in the first instance perceive as a result of an impression by an external object on a sense, we come by instinct or experience to consider certain constant combinations of sensations as the expression of certain external objects, and thus acquire a belief in their existence.

Is the testimony of one sense sufficient for this?

It is especially by the concurrent testimony of the different senses that we are led to conclude as to the real

existence of something which we consider external objects. Thus, if, at the same time we experience a tactile sensation, we perceive a corresponding visual appearance, we have reason to conclude as to the existence of something which (in the case of touch, by its direct impression—and in the case of vision, by the mediate impression of light) excites the two sensations; and this belief as to the existence of something external is strengthened if we find, on striking what appears to be, through touch and vision, the object, we hear a sound—if we apply our tongue to it, we become sensible of a taste—or if we direct the nose to it, we perceive an odour.

What, on the other hand, would lead us to doubt that a tactile sensation—such as that like ants creeping on the skin, for example—is really caused by the impression of an external object?

If, on directing our attention to the part to which we refer the sensation, by means of the other senses, they do not concur in testifying to the presence of any external object making an impression on the skin.

Are subjective ever actually mistaken for objective sensations?

Not unfrequently: especially by weak-minded people, as in the following case—A woman, from some disease of the brain, became subject to seeing flashes of light before her eyes, and fell into the hallucination of supposing that people had everywhere conspired to annoy her by throwing glares of light into her eyes.

How do we, at an early period of life, get acquainted with external objects by means of all the *senses*?

By an instinct implanted in the mind of the child, it curiously submits objects to the scrutiny of all the senses. The eye follows the dazzling toy—the hand grasps at it and conveys it to the mouth, that the taste may be interrogated. Does a sound fall on the ear, the eyes are immediately called into requisition to search for the sounding body.

How is it that we are subsequently enabled to recognize an object again, even when one sense only is impressed by it?

By association; the present observation by one sense recalling to mind the past observations of the same object by the other senses.

But might not two very different objects present appearances to the examination, by one sense only, so very similar, that the mind might be deceived by trusting to the examination by that one sense alone?

No doubt we are often deceived by being satisfied with limited observation.

Suppose we became acquainted with an object through one sense only—say, touch—would it be possible for us to identify the object again by means of another sense—say, sight—to the scrutiny of which the object had never before been subjected?

Not directly; persons blind from birth, upon having sight restored by operation, cannot recognize by the eye what they had before felt with their hands, till they have again examined the object concurrently with both senses.

Do such cases give any support to the supposition of Molyneux and Locke—viz., that a person blind from birth, if suddenly restored to sight, would be unable to distinguish, by the newly acquired sense, between a globe and a cube?

They do not. The person, no doubt, would be unable to determine at once that the cube was the body he was already acquainted with as a cube, by the touch; but he would be able to see that the cube and globe were of different shape, and therefore would be able to distinguish between them.

§ *Apparitions.*

Is there any foundation for the popular belief in apparitions or spectres?

Yes; but not to the extent that there is anything supernatural in them.

On what does the appearance of spectres depend?

In some cases, on after-sensations; in other cases, on the reaction of the mind on the senses.

Explain the occurrence of apparitions dependent on the retention of visual sensations.

In certain excitable states of the eye or mind, after-sensations persist for a much longer time, and are more vivid, than usual. To persons not aware of the retention of sensations by the retina, their occurrence, when thus strongly marked, appears startling and mysterious. Thus it may happen, that in the twilight, a person, after having unconsciously rested his eyes on some dark object, such as a post, will, on looking towards the grey sky, see a magnified and white image of it;

this, with a little assistance from the terrified imagination, may readily be taken for a figure dressed in white. Sensations being retained only for a short time after the impression has ceased, the supposed apparition in white soon vanishes into thin air.

Does anything similar to these apparitions from after-visual sensations occur in the case of the other senses?

Yes, especially in the case of touch; but they are not so productive of illusions as the after-sensations of sight.

Explain the occurrence of apparitions having their origin in the reaction of the mind on the senses.

The mental state excited by some strong impression, or by long brooding on a cherished scheme, may, by its reaction on the senses, give rise to a vivid production of phantasms relating to the predominating idea. Such apparitions are, however, of most common occurrence in disease, under the influence of opium and other narcotics, in drunkard's delirium, and in insanity. They may, indeed, present themselves to persons otherwise healthy though in an excited state, either from original temperament or in consequence of being placed in exciting circumstances; and, of course, exciting circumstances will operate still more strongly on a person already excitable from original temperament. In some persons there is a natural disposition to phantasm-seeing.

Do analogous phantasms occur in the domain of the other senses?

Phantasms of touch are exemplified in the pains and other peculiar sensations of hypochondriacs. In regard to

phantasms of hearing, people sometimes imagine that they hear not only sounds, but also spoken words. The phantasms of vision are those, however, which have attracted most interest. Appearances as if of various objects—landscapes and figures, for example, even walking figures—present themselves before the eyes. Phantasms of both hearing and vision may occur together—the human figures seen being, at the same time, heard talking. In the celebrated case of Nicolai, the Berlin bookseller, the phantasms were at first *seen* only, but after a time were *heard* also.

SECTION III.—NATURE OF OUR KNOWLEDGE OF MIND AS DISTINCT FROM BODY.

What notions have we of mind as distinct from body?

From our consciousness we infer the existence of that in us which is the conscious agent—viz., the mind. On the other hand, referring the sensations of which we are conscious to the body as their seat, the mind concludes the body to be something extrinsic to itself. We have thus a belief in the existence of mind and body as constituting our individual man: the mind being both subject and object of consciousness, the body object only.

Seeing that we are conscious of the existence of the mind only in connection with the body, might not the mind be viewed as a mere property or endowment of the body?

Certainly not: the very constitution of our mind, which

leads us to interpret sensations as signs of external material objects, as truly leads us to recognize, from our consciousness of self, the mind to be an entity distinct from the body—an intelligent immaterial principle—the soul or spirit, in other words.

Is it by induction or deduction that we infer the existence of mind from our consciousness?

Neither by induction or deduction, but by intuition. As, however, we infer many things regarding the properties of matter by induction and deduction from objective phenomena, so from subjective phenomena we infer, by the same process of reasoning, many things regarding the properties of mind.

Explain how.

As we subject external objects to observation and experiment, so also can we subject the mind to similar investigation; that is, the mind can subject itself to investigation by itself.

What is the nature of the relation between soul and body?

Whilst it is true that the mind or soul is not a mere property or endowment of the material body, it is also true that the life of the body is not an emanation of the immaterial mind or soul, but truly a property or endowment of the material body.

Explain yourself more in regard to the life of the body.

The life of the human body is, in fact, a mode of activity peculiar to it as an organized material structure, and is

identical in essential nature with the life of the body of the lower animals, and also of plants.

Whilst the life of the body of man, like that of the bodies of animals and plants, is thus merely a peculiar mode of activity with which the body, as matter in certain combinations and forms, and under certain conditions, is endowed, what is the death of the body?

The death of the body is merely the cessation of that mode of activity—the cessation of the powers and capacities of the body—in consequence of a breaking up of those material combinations and forms, and a cessation of those conditions necessary for their maintenance.

Though the body of man thus dies, like that of the lower animal and the plant, what becomes of his soul or spirit?

Independently of revelation, we have an intuitive belief that it survives. Being immaterial, however, it ceases to manifest its powers and capacities here in this material world, in consequence of the dissolution of the material agent—the body—by which alone it can manifest them here.

The human soul, in short, does not animate the body, but inhabits the animated body, and, through it, holds converse with this material world?

Just so.

We have seen that the brain is the organ of the body through which the mind works. Now what

is known of the nature of the mind's connection with the brain?

Nothing. All that we can say on the point is, that, by virtue of certain unknown changes in the state of the brain, the mind perceives sensations, and fulfils its volitions.

SECTION IV.—NATURE OF OUR KNOWLEDGE OF GOD.

What can we know of the existence of God, who is the object of none of our senses?

The essence or substance of God we are, indeed, incapable of comprehending; but, as above shown, we are equally incapable of comprehending the essence or substance even of things material, which are the objects of our senses. The same constitution of mind, however, which leads us to a belief in the existence of an external material world, and of the mind itself as a distinct entity from the body, as truly leads us to a belief in the existence of God.

Is it by induction or deduction that our mind is thus led to a belief in God?

Primarily, it is neither by induction nor deduction, but by intuition. As, however, we infer many things regarding the properties of matter, by induction and deduction, from objective phenomena, and many things regarding the properties of mind from subjective phenomena—so, starting from our intuitive belief in God, we infer many things regarding the divine attributes, from contemplating the marvellous manifestations of wisdom, power, and goodness, in the creation around us.

What does revelation teach?

It confirms our belief in God, and explains His dealings with man.

SECTION V.—OBSERVATION OF FACTS.

Repeat what our knowledge of the material world around us really consists in.

All our knowledge of the world around us resolves itself into phenomena or appearances, which the mind perceives as a result of the impression of external objects on our senses.

How then do we know anything of the actual existence of the material world?

Whatever we do know of it, is known only by immediate intuition.

What do you mean by a fact?

An association of phenomena observed simultaneously or in succession.

When the phenomena are observed simultaneously, what kind of fact have we before us?

An object.

When the phenomena are observed in succession?

An event.

Is it easy to ascertain facts?

It is not, judging by the frequency of error.

What is a very common cause of error?

The prejudices of the mind, which lead us to substitute mere opinion for fact.

This is an error, it would seem, which might be easily avoided?

Experience shows to the contrary. To take cognizance simply of what is appreciable by the senses, without mixing the observation up with any opinion or fancy of our own, is, indeed, an effort of the mind more difficult than can readily be imagined by those who have not been led to reflect on the matter.

What extraneous causes of error have often interfered with the acquirement of correct knowledge?

The mistaking of mere forms of words for realities, and blind submission to the authority of a name.

Describe the method of acquiring knowledge by induction from facts.

The method consists in first making ourselves acquainted with particular facts by observation and experiment; secondly, in tracing the connection in which the ascertained facts stand to each other, so as to discover some other fact or some more general expression of the facts; thirdly, in drawing, from such generalizations, still more general and comprehensive truths.

What do you mean by observation and experiment?

By observation is meant the taking note of phenomena as they ordinarily present themselves in nature; by experiment, on the other hand, is meant a new disposition of the objects to be observed, which we may be able to make, in order to

bring the phenomena into a new combination—that is, bring about a fact which would not otherwise occur. Observation, it will thus be seen, is included in experiment.

Give examples, from the subjects which have been engaging our attention, of observation and experiment respectively.

That the nerves which arise from the spinal cord have two roots is a matter of anatomical observation ; whilst, if we lay bare these two roots in a living animal, and find, on irritating the anterior, that contractions of the muscles to which the nerve is distributed are excited, but, on irritating the posterior, that the animal gives indications of pain, we have performed a physiological experiment.

Wherein consists the method of acquiring knowledge by deduction ?

Deduction is a method, the converse of that by induction, leading us from general to particular truths: the method is thus, at the same time, a valuable means of testing the correctness of our inductions.

But how are the general truths you set out from, in deduction, first established ?

By induction : thus it was that Newton, by his grand induction of universal gravitation, at one stroke transformed astronomy into a deductive science.

In framing our inductions and deductions, what conditions do we presuppose ?

The constancy of the laws of nature—that things will continue to be as they have been.

SECTION VI.—INSTINCT.

What is instinct?

Instinct is that innate disposition of animals whereby they are impelled to the performance of certain actions, and no other, under given conditions.

To what do such actions tend?

Though performed without design or forethought, on the part of the animal, as to the result or its utility, the actions are most perfectly adapted to accomplish what is necessary for the well-being of the animal and the purpose it is destined to serve in the creation.

In what respect do instinctive actions differ from actions dictated by experience?

Instinctive actions are performed as well at first as afterwards, and are invariably the same in all animals of the same species.

Show that imitation has nothing to do in the case.

Chickens hatched by artificial heat instinctively pursue the mode of life peculiar to their species, without the example of a mother; whilst ducklings hatched by a common hen as certainly follow their instincts by running to the water in spite of all the warnings and wailings to which their foster-mother, actuated by contrary instincts, gives expression.

How is intelligence in animals, as compared with instinct, manifested?

Animals endowed with intelligence are able to adapt their

actions to suit particular circumstances, so as to accomplish the same ends by different means; and the faculty of doing so is capable of being improved and perfected by experience and imitation.

Is intelligence in any of the lower animals so great as to predominate over instinct?

No; in even the most intelligent animals, instinct still in a great measure supplies the place of intelligence.

How is it with man?

In man, intelligence supersedes instinct.

But is not man endowed with instincts?

Man also has his instincts, but they are subordinated to his reason.

In what cases is human instinct most manifest?

In infants, before the reason is developed; and in idiots, in whom development of the reason has been arrested.

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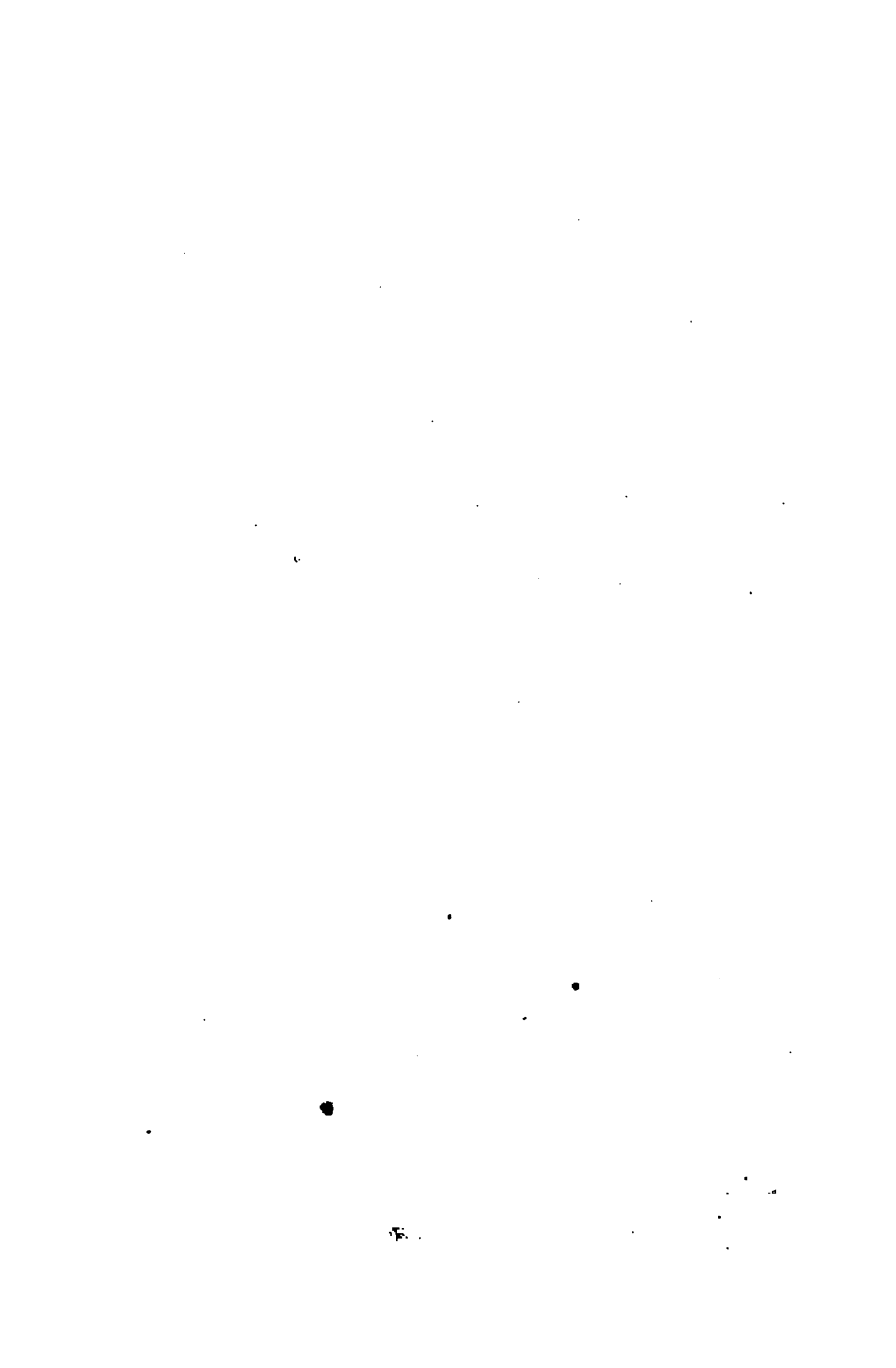
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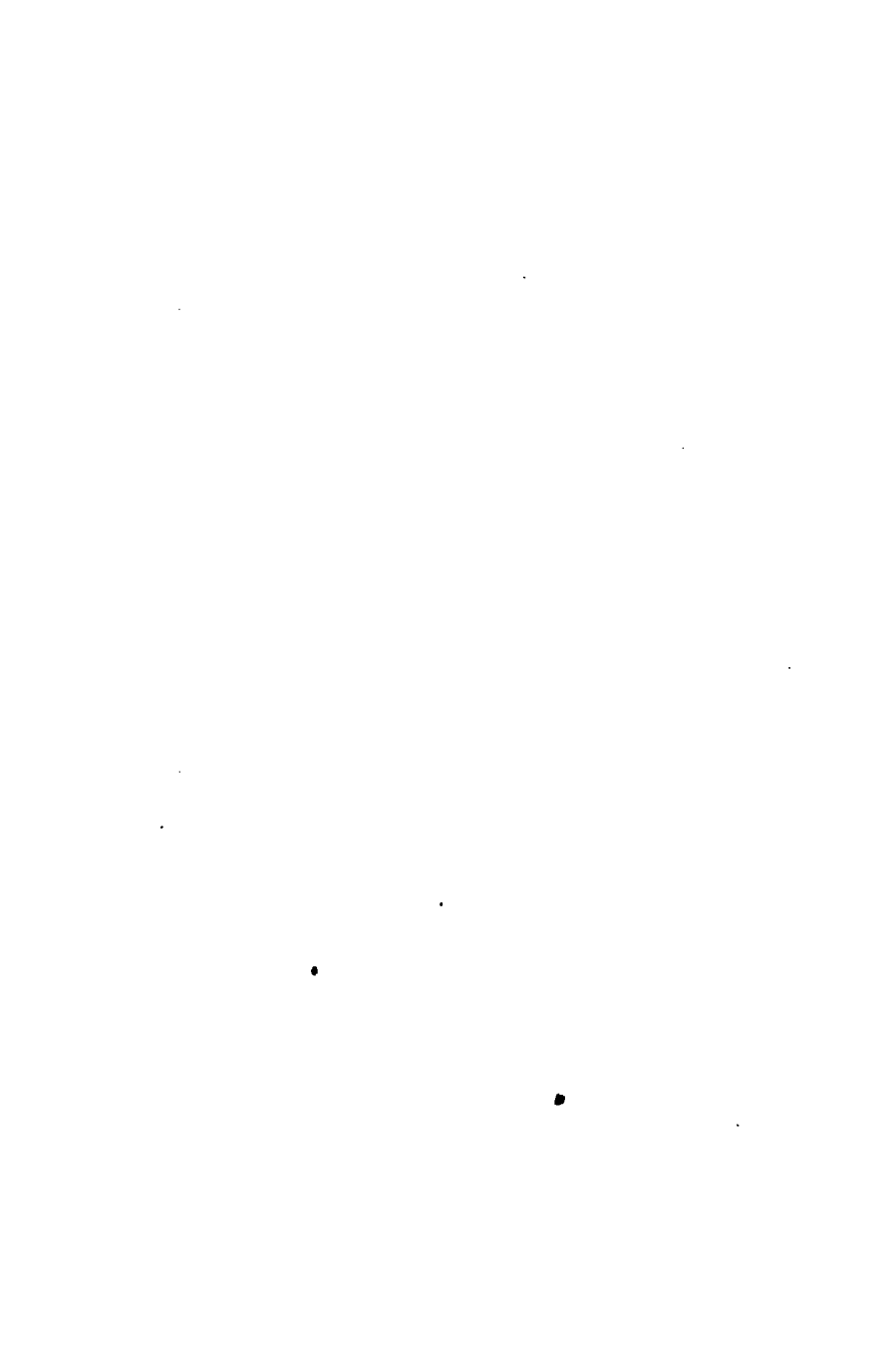
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